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(NASA-CR-194702) CONCEPT REPORT: EXPERIMENTAL VECTOR MAGNETOGRAPH (EXVM) OPERATIONAL CONFIGURATION BALLOON FLIGHT ASSEMBLY Final Report (Teledyne Brown Engineering) 57 p

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CONCEPT REPORT
EXPERIMENTAL VECTOR MAGNETOGRAPH (EXVM)
OPERATIONAL CONFIGURATION BALLOON FLIGHT ASSEMBLY

December, 1993

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Prepared For:
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Marshall Space Flight Center
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EXVM CONCEPT REPORT

1.0 INTRODUCTION

Building on the existing data base which was compiled from solar balloon concept studies under contract NAS8-38089, Teledyne Brown Engineering (TBE) has performed this present study for adapting the ground based Experimental Vector Magnetograph (EXVM) to fly on a balloon. Figure 1 gives a pictorial representation of the proposed flight concept developed for this report. The concept includes the relative placement of the various elements of the scientific package, the mission support equipment, and the balloon flight hardware. Figure 2 shows all the hardware operational interfaces in a pictorial form. Details of the systems presented and their operational interfaces will be discussed in the subsequent sections of the report.

The observational limitations of earth bound solar studies has prompted a great deal of interest in recent months in being able to gain new scientific perspectives through, what should prove to be, relatively low cost flight of the magnetograph system. The ground work done by TBE for the solar balloon missions (originally planned for SOUP and GRID) as well as the rather advanced state of assembly of the EXVM has allowed the quick formulation of a mission concept for the 30cm system currently being assembled. The flight system operational configuration will be discussed as it is proposed for short duration flight (on the order of one day) over the continental United States. Balloon hardware design requirements used in formulation of the concept are those set by the National Science Balloon Facility (NSBF), the support agency under NASA contract for flight services.

The concept assumes that the flight hardware assembly would come together from three development sources; the scientific investigator package, the integration contractor package, and the NSBF support system. The majority of these three separate packages can be independently developed; however, the computer control interfaces and telemetry links would require extensive preplanning and coordination. A special section of this study deals with definition of a dedicated telemetry link to be provided by the integration contractor for video image data for pointing system performance verification. In this study the approach has been to capitalize to the maximum extent possible on existing hardware and system design. This is the most prudent step that can be taken to reduce eventual program cost for long duration flights. By fielding the existing EXVM as quickly as possible, experience could be gained from several short duration flight tests before it became necessary to commit to major upgrades for long duration flights of this system or of the larger 60cm version being considered for eventual development.

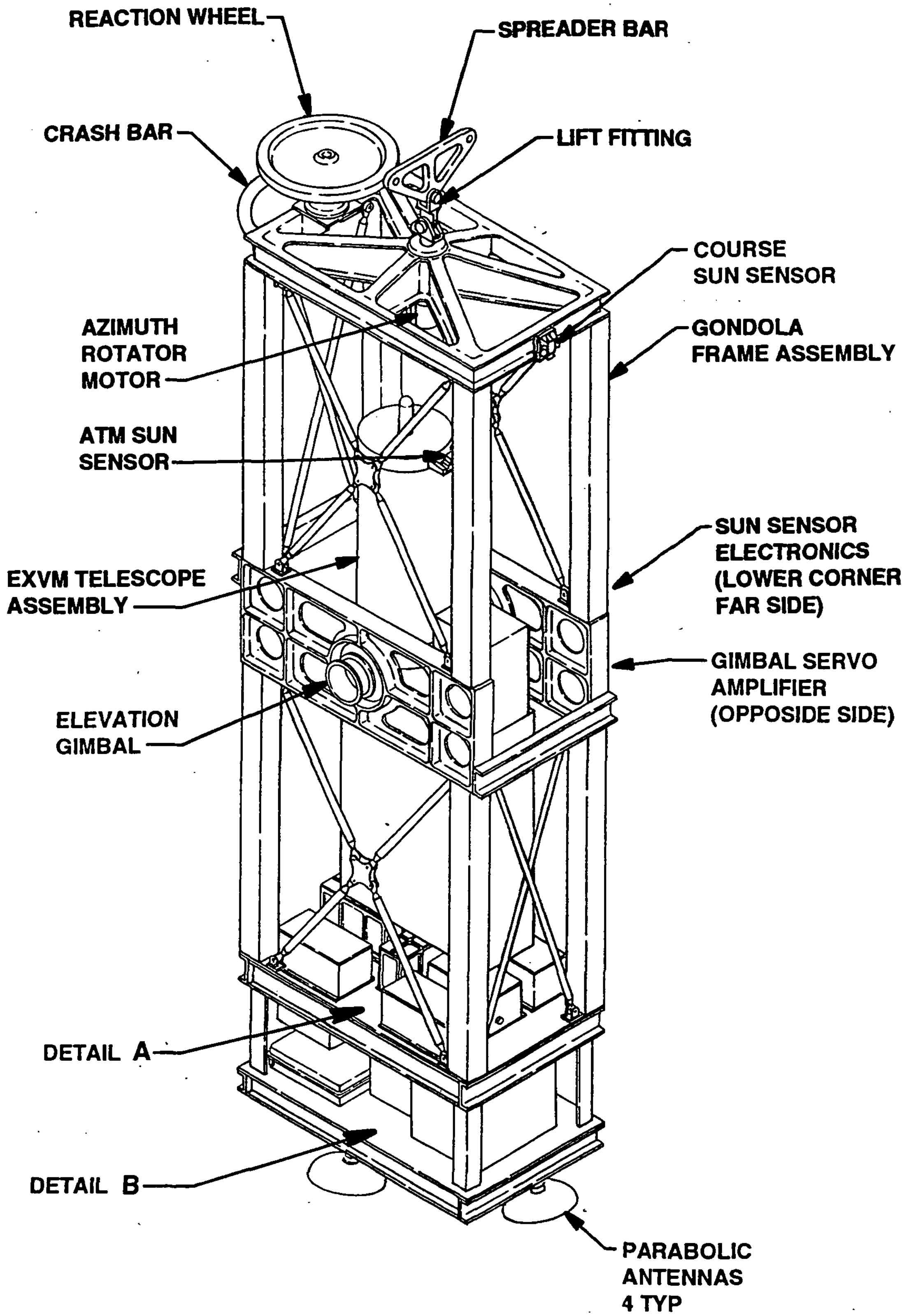
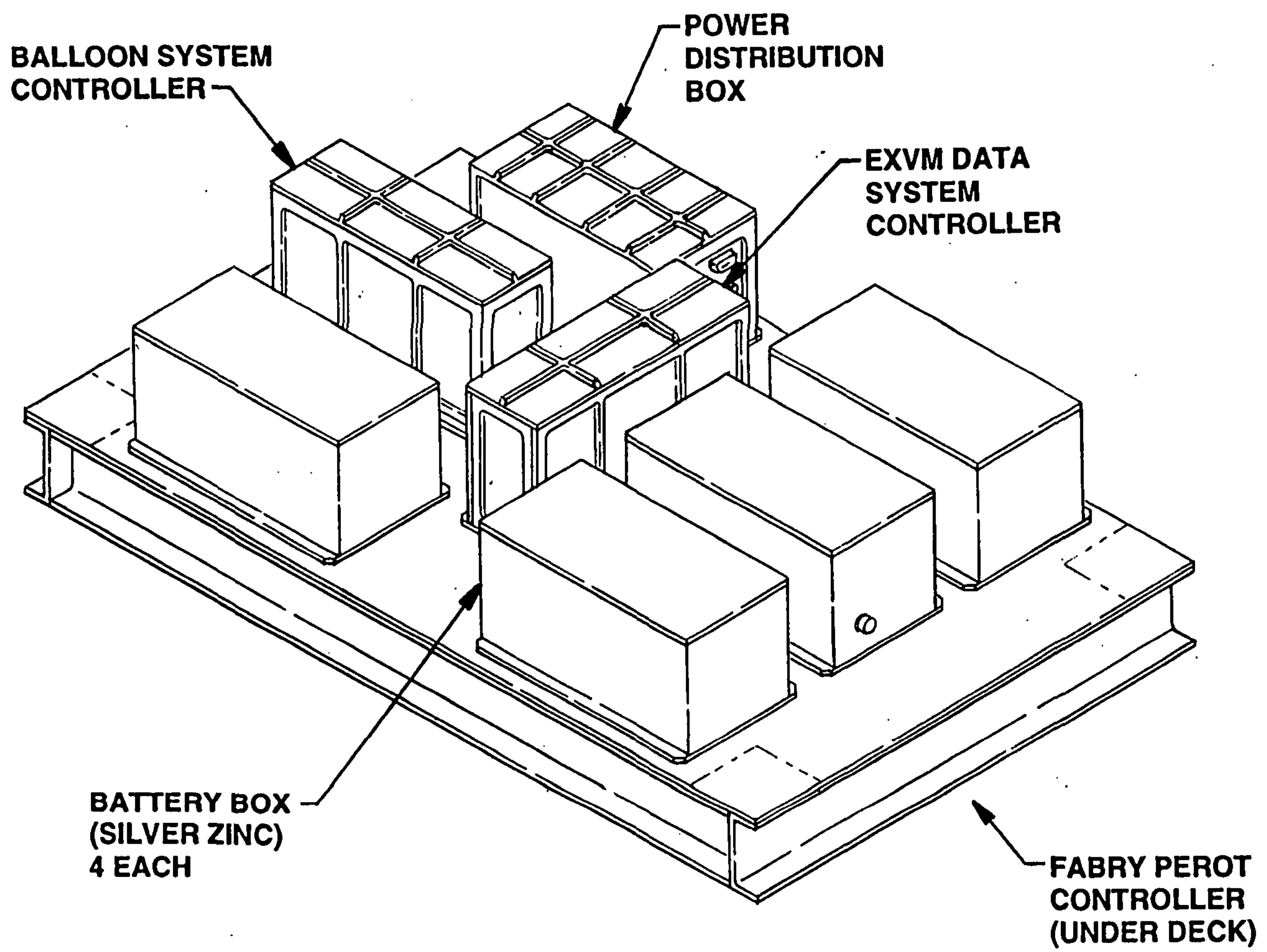
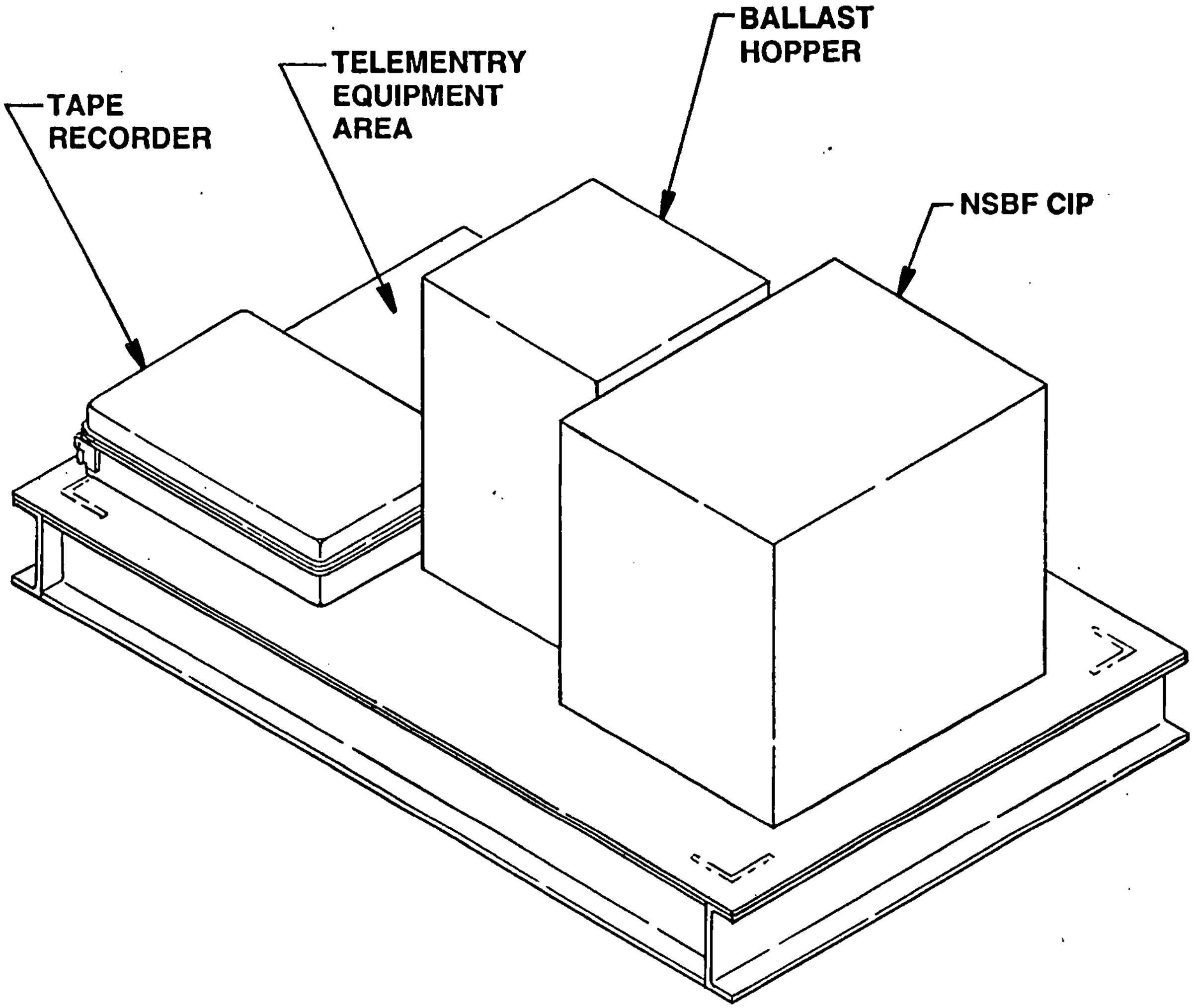


FIGURE 1
EXVM CONCEPT
BALLOON FLIGHT CONFIGURATION
(Sh 1 Of 3)



DETAIL A

FIGURE 1
(Sh 2 OF 3)



DETAIL B

FIGURE 1
(Sh 3 Of 3)

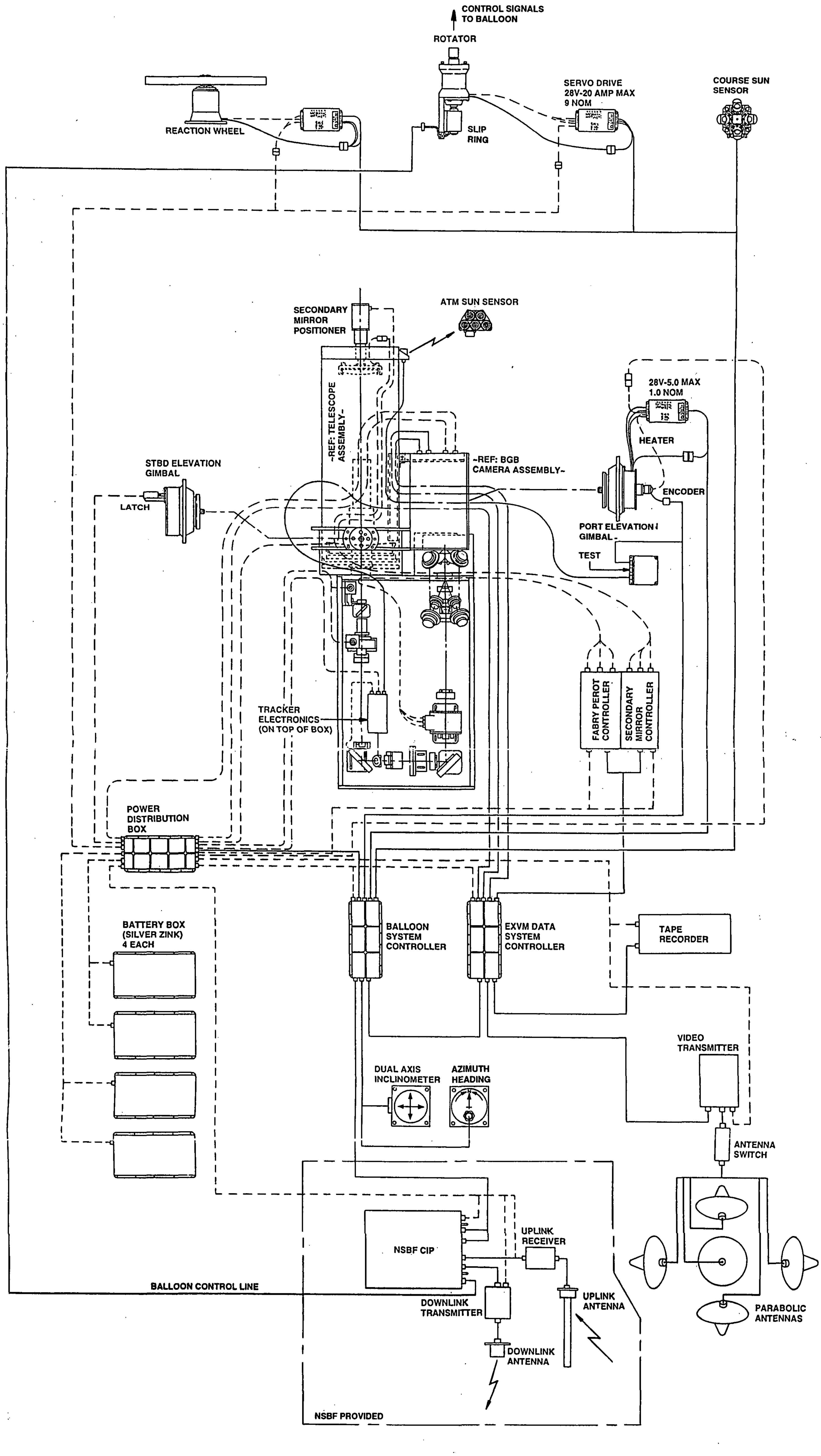


FIGURE 2
EXVM INTERCONNECT DIAGRAM

2.0 SCIENTIFIC PACKAGE DESIGN

2.1 OPTICAL SYSTEM

The EXVM, a telescope optical assembly used to study the magnetic fields around solar flare fields, has been under development at Marshal Space Flight Center (MSFC) for the past few years as a new scientific system in the solar observatory facility, Bldge 4347. The same basic technology to be employed in the EXVM has been used at MSFC since 1973 in an existing magnetometer system. The EXVM, however, employs an upgraded optical lens, filter, and detector system which is designed to gather higher spatial resolution polarized data on the sun spot magnetic field activity. The key to the systems performance improvements over the existing ground based unit is the CCD camera at the final image focus. The camera detector has been designed to receive a 4 x 8 arc minute solar image which has been split into four equal parts and focused through a special series of lenses and mirrors onto four 1024 x 1024 pixel receptors. The CCD chips are only illuminated over half their detector area (the other half being masked off). Because the chip read out is the limiting factor on performance speed, this masking allows the chip to transfer the active pixel data from one image to the inactive storage area for read out while the active area is receiving a new image. These read outs viewed as snap shot frames are averaged over various time intervals and various polarization states in order to complete what is considered one finished image. For a balloon flight the frame data would be processed on board by the associated scientific data system and the results stored on tape for later analysis.

The EXVM has been developed for use with an existing 30cm Cassegrain telescope and optical mount at the observatory facility. The optical lens and filter design arrangement was developed by the University Of Alabama at Huntsville's Optics Department and is shown in Figure 3. Using the layout of Figure 3, the mechanical design for a ground based optics box was developed and built by TBE for MSFC. Design for most of the lens holders was also prepared and are currently under fabrication in house at MSFC. The adaptation of this ground based optical assembly design for flight is depicted in Figure 4. Light entering the telescope tube will encounter a specially coated prefilter to remove 60% of the unwanted wavelengths. A filter wheel or linear positioner would be located behind the primary mirror to allow various lens or target elements to be inserted in the light stream. A sharp edged field stop (aperture) will reduce the solar disk image to a close approximation of the final 4 x 8 arcminute size to be studied. The unwanted light would be rejected from the optics box. The polarimeter is mounted on a rotary positioner to allow its incremental clocking for polarization of the light in various planes. A gimbal mirror is provided at the first optical fold. This mirror is mounted in dual servo axes gimbals which can steer the image for minor motion compensation. The electronics for the tracker assembly would be located on top of the optics box and would receive a separate copy of the light stream from a beam splitter located immediately after the fold mirror. A blocking filter, the next optical element of interest, would reduce the incoming wavelengths to a very

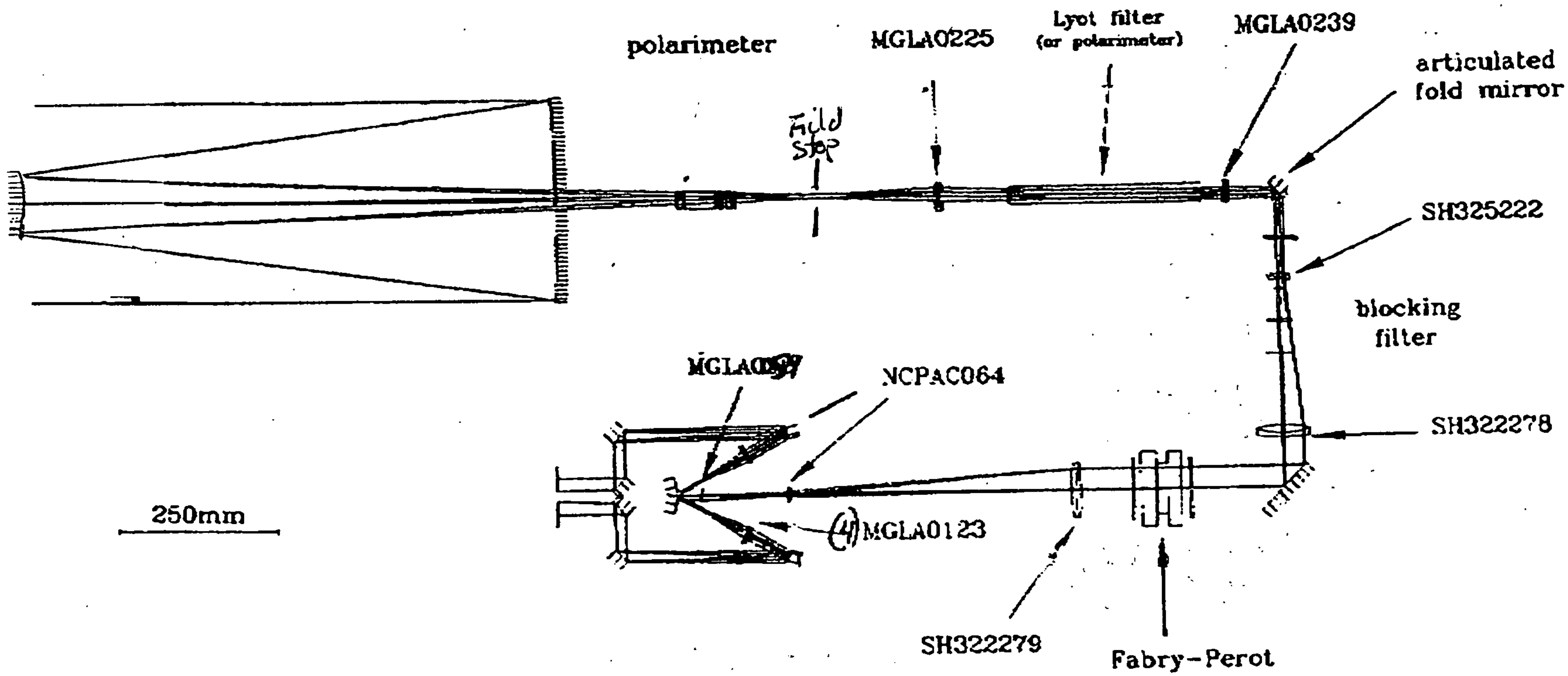


FIGURE 3
EXVM OPTICS DESIGN

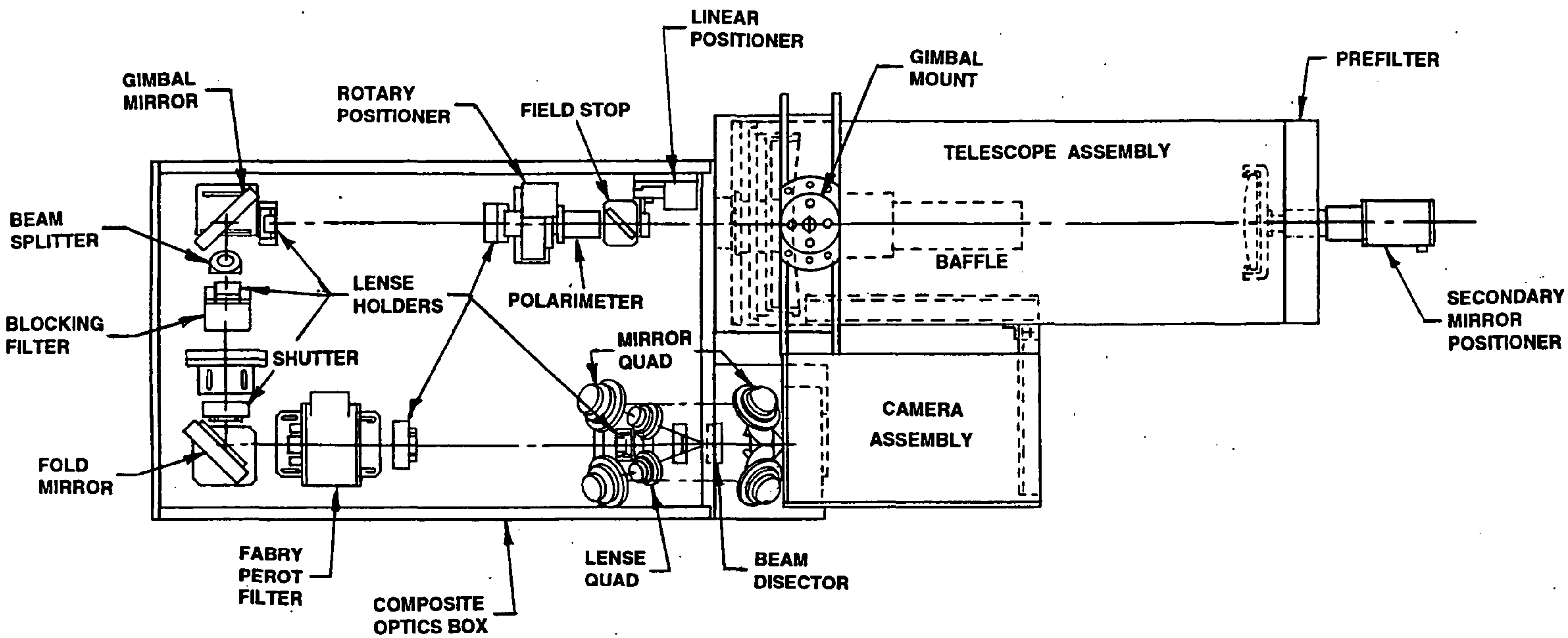


FIGURE 4

EXVM TELESCOPE OPTICS ASSEMBLY

narrow band around the frequency to be studied. A Fabry Perot filter located later on down stream adds further to the wavelength controls by restricting thru put to virtually a single frequency. A pyramid shaped mirror would be used in the beam dissector to separate the field of view into four parts for illumination of the camera chips. The dissected beams have to pass thru a lens and three more mirrors before they can enter the camera in the proper orientation. A software routine will electronically recombine the image field during data analysis. The camera is currently technology limited by available chip performance; however, in the near future it is hoped a 2048 x 2048 chip will become available which meet the EXVM requirements without the used of the complicated beam dissector.

2.2 TELESCOPE MECHANICAL DESIGN

For a low cost initial flight instrument, it is proposed that the existing 30 cm Cassegrain system and the attached optics enclosure be repackaged in a graphite epoxy housing to eliminate the aluminum hardware currently in use. Proper design of this new structure could almost complete eliminate any concerns for thermal distortion of the image due to lens movement along the optical path. The new housing would have provisions for attachment of trunnion fitting that in turn fasten to the pointing and control system elevation gimbals. The trunnion fittings would be placed as close as possible to the projected CG location of the instrument. Provisions would be made to allow minor ballast placement to trim a zero moment at the fitting in the flight condition. All the system cables and lines would pass across from the instrument package to the gondola around these fittings. The number and stiffness of these cables will have a direct impact on the pointing stability of the instrument so every effort will be made to reduce the cross over interfaces necessary for flight. The enclosure would be coated black internally and white externally for heat and light control. Elements of the optical train or the electronics which require additional thermal control (reference section 4.0) would have heat sinks built into the enclosure for that specific purpose. Attachment provisions would be located for individual equipment mounting. Lens and filter holders would incorporate necessary alignment adjustment provisions.

2.3 ACTIVE SECONDARY MIRROR DESIGN

As an option to the gimbal mirror system currently being developed for the ground based EXVM it desired to have the option of using active secondary mirror control for minor image motion compensation. Based on an analysis of the type, accuracy, and degree of motion required to be produced by the secondary mirror system, TBE proposes that a system based on Piezo electric stack technology would be the optimum choice for mirror actuators; therefore the focus of potential vendor selection was toward companies with expertise in this field. It is felt that a combination of controller hardware could be made since the Fabry Perot filter, currently used in the EXVM optics, already has a PZT operating system. The vendor for that system has identified what redesign would be required in order to make that system suitable for balloon flight.

The gondola pointing system performance will have to be compatible with the motion control philosophy and performance of this secondary mirror system. Because the gondola system has not been fully developed yet, and no operating simulations have been run, it was not feasible to assess the interactions between the two operating systems. For concept definition purposes it was felt, however, that the secondary mirror system should provide as much image motion compensation as could be technically achieved. How much motion can be provided depends on the physical as well as the optical constraints of the overall system. For example, the telescope field of view is approximately 48 arc minutes; however the image quality beyond a solar diameter (approximately 30 arc minutes) degrades rather rapidly for the scientific purposes. The magnetograph will employ a field stop of slightly larger than 4 x 8 arc minutes. To keep the area of interest fixed on the field stop, the image motion system would be physically constrained by the quality of the field of view of the telescope to approximately +/- 8 arc minutes of motion. To allow for a control system margin in rate of motion, time to restore,and the possibility of future limb sensors, this motion was further restricted to give a mirror control range of +/- 4 arc minutes.

The optics design consultants (UAH) was asked to verify that a four arc minute (4") rotation of the secondary mirror would not produce undesirable polarization effects in the image. UAH confirmed that this would not to be a problem with the proper selection of mirror coatings for the primary and secondary mirrors. In addition UAH determined that a 0.17 degree rotation of the secondary mirror itself was necessary to provide the 4" motion in the image.

Queensgate, the Fabry Perot vendor, has responded to an inquiry for an active secondary mirror system as described. They have proposed furnishing the actuators and controls (drivers); however it would be up to the integration contractor to package the mirror assembly.

2.4 SUPPORT ELECTRONICS

The scientific package will have several support electronic elements, some of which it would be possible for the integration contractor to provide. For this study the scientific package responsibility will be assumed to include:

EXVM Data System Controller
Tape Recorder
Fabry Perot Controller
Secondary Mirror Controller
Tracker Electronics
Camera

The main EXVM controller will have interfaces to the power distributor, the pointing and control system, and the telemetry command and control system via its interface with the balloon controller. Section 5.0 discusses the options for a video image

telemetry system which would have its primary input interface from the EXVM controller, but would be under executive control of the balloon system controller.

The quantity of data that will be accumulated from a single eight hour day of scientific observation has been estimated to be extremely large and several efforts have been made to find compression routines to reduce the storage volume required. To date no acceptable compression method has been found. The tape recorder proposed for the balloon flight concept is really an Exabite 8500 with a ten cartridge library system and a robot loader,Model 10i. The 8mm tapes are rated for 5 gigabytes of data storage and the ten units in the library would archive 50 gigabytes for the mission. The commercial unit would be repackage in a special housing for environmental purposes of flight.

3.0 INTEGRATION PACKAGE DESIGN

The balloon integration package consists of the gondola structure, any active and/or passive thermal control systems, power supply and distribution, the scientific package pointing and control system, and the executive mission command and monitor equipment. The video telemetry system is included in the integration package for this study and a separate contractor study of a flight hardware concept is given in Section 5.0. In addition to the mission support hardware, system integration tasks critical to mission success, weight and power control are also discussed.

3.1 STRUCTURE / WEIGHT

The gondola structural concept shown in Figure consists of a machined one piece aluminum upper frame to which the rotator and reaction wheels are attached. The vertical members of the gondola cage are composite tubes with integrally epoxied end fittings for attachment to the upper frame and the base. The two large box side structures for mounting the elevation gimbals are also machined aluminum. The base frame, in two separate layers, is made up of various composite channel members fastened by corner clips with thru bolts. Deck plate is placed over top of the channels to stiffen the structure and support the electronic boxes. The plate would either be aluminum or a composite honeycomb panel. The vertical leg members are also stiffened by cross members and diagonal links where possible. As can be seen the lower deck level has a cut out in its center for installation of the NSBF provided ballast hopper. The structural assembly would have to meet the NSBF flight load design requirements and it would have crash pads mounted at various locations to absorb ground impact loads following flight.

Weight of the flight system is a key design factor. A launch weight limit of approximately 3,500 pounds is the design value used for flight in the continental US. A major portion of that 3,500 lbs; however, is required to be ballast weight in order to keep the balloon at altitude during the observation period. Table 1 gives a preliminary mission weight estimate and includes the NSBF equipment weight and a launch allocation of 1,500 pounds of ballast.

Table 1- EXVM BALLOON MISSION WEIGHT ESTIMATE

Item	Weight (lbs)
30 cm Telescope:	
Tube	80.0
Secondary Spider	5.0
Secondary Mirror	0.9
Sec. Mirror Holder	1.5
Focuser	6.0
Primary Mirror	20.0
Pri. Mirror Holder	8.0
Interface Ring	6.5
Baffles	2.5
Base Plate	8.0
Prefilter:	
Lens	28.0
Lens Holder	10.0
Mount Ring	6.0
Mount Structure:	
Rings	4.6
Braces	8.0
Saddle	10.0
Trunions	4.0
Optics Assembly:	
Linear Positioner	5.0
1/4 Wave Pl & Holder	1.0
Polarimeter	5.0
Rotating Positioner	10.0
Lens 225 & Holder	1.2
Lyot Filter	23.5
Folding Mirror	2.5
Lens 235 & Holder	1.0
Beam Splitter	0.8
Correlation Tracker	4.0
Lens 32522 & Holder	1.2
Blocking Filter & Holder	1.6
Mirror & Lens 322278	2.5
Fabry-Perot	14.0
Lens 322279	1.5
Lens PAC064	0.8
Camera Lens Assy	10.0
Camera Head	16.0
Optical Box	30.0
Box Covers	20.0
Cables	18.0
Telescope Subtotal: (Pointed Mass)	(378.6)

Table 1 - EXVM Weight Estimate (cont.)

Science Support Equipment:	
Camera Electronics Box	34.0
Data System Box	20.0
Tape Recorder	54.0
Tracker Electronics	10.0
Fabry-Perot Controller	25.0
Secondary Mirror Controller	20.0
Subtotal =	(163.0)
Balloon Integration Equipment:	
Motor Control Box	40.0
Power Distribution Box	30.0
System Controller	24.0
Elevation Gimbals	92.0
Azimuth Rotator	54.0
Reaction Wheel	50.0
Sun Sensor	2.0
Thermal Control Sys	10.0
Batteries	240.0
Cables (Est.)	50.0
Insulation	12.0
Hardware	10.0
Gondola Structure (Budget)	275.0
Subtotal =	(889.0)
Science Equipment Total =	1,430.6
Launch Weight: + CIP	270.0
+ Ballast	1,500.0
+ Parachute&Rigging	300.0
Flight Total =	3,500.6

3.2 POINTING AND CONTROL SYSTEM

The EXVM pointing and control system consists of a number of active elements used to acquire a preselected sun spot, lock the optics train on the desired target and track it in a stable manner during balloon motions, so that, the image remains sufficiently fixed during the data integration cycle. The elements of the P&C system include the sun sensors, the reaction wheel, the rotator, the elevation gimbals, and the system controller, reference Figure 1. As was already discussed the EXVM optics system has an internal motion compensation system that would also play a part in the total image control operations.

Two types of sun sensors have been included in the P&C system concept. One is a course sensor array to be mounted on the upper front face of the gondola frame. This array would indicate when the sun was in the front plane of the structure and would be used for initial solar acquisition. A second sun sensor, the ATM sensor, would be mounted on the end of the EXVM telescope tube. This sensor has a narrow field of view and would be used to keep the telescope pointed at the solar disk. The EXVM tracker electronics would then be used to translate across the solar disk in a manner to acquire the preselected sun spot target. Error signals from the tracker electronics would be used to drive the elevation gimbals, the rotator and reaction wheel, and the secondary mirror or compensation mirror drives.

The elevation gimbals will provide the primary pointing torque to the science package. A gimbal is located on either side of the telescope assembly; however only one gimbal is driven and the other simply follows with a latching feature for the stowed position. An optical encoder on the drive gimbal will provide feed back of the actual gimbal position versus the commanded position. Rotational torque is applied to the entire gondola structure by the rotator located at the interface with the balloon lines. Use of the rotator will constantly cause a disturbance torque, since the balloon lines will be twisted by the incremental torque steps needed to produce rotational motion. Various schemes of rotational control will be analyzed and tested before a final selection may be implemented. The reaction wheel allows minor rotational corrections without stepwise disturbance torques; however in order to restore the wheel speed to a mid range value after a series of corrections a stepwise rotator torque must be applied. These two devices must be designed to operate in concert and be compatible with the internal image motion compensation system performance.

The key to the pointing and control system operation will be development of the control software resident in the balloon system controller, tracker electronics, and the EXVM controller. The tracker software will include the ability to recognize the specified sun spot and to hold its position (specifying output slew error rates for the control system). Close coordination will be required between the science package and the integration contractor to jointly develop and debug these software routines.

In addition to the pointing and control function, the balloon controller will be the primary housekeeping and status interface link to the ground (through the NSBF data

link). All in coming ground commands will also be routed to the balloon controller for execution or forwarding. To aide in data analysis and operation of the pointing system, two other sensors have been tentatively included in the interconnect plan of Figure 2. These are a two axis inclinometer to measure gondola roll angle, and an azimuth heading sensor to provide balloon heading at float altitude. The azimuth sensor would also help in initial acquisition of the sun.

3.3 POWER SYSTEM

For short duration missions, batteries are the only source of power provided in the gondola assembly. The concept given in Figure 1 shows four silver zinc battery packs are provided for a typical mission. Each pack consists of 19 (1.5 volt) cells wired to give a nominal 28.5 volt DC operating system. Each pack is rated at 100 amp hours. Table 2 gives an approximate estimate of the mission power requirements. The power distributor box will be the central distribution and regulation point for all the science and balloon system hardware. Circuit breakers internal to the box will\ permit independent control of almost all components. In addition current monitors will be provided on the key power circuits to provided over load cutoff if out of tolerance current demand is registered. Figure 2 gives a pictorial view of the concept interconnects and a complete set of cable sketches is given in Appendix A.

3.4 THERMAL CONTROL

A number of the EXVM optical elements are potentially very sensitive to thermal temperature changes. The elements of concern are the optical path/lens holders, Blocking Filter, Fabry Perot, and camera. The batteries and electronics in the entire balloon system are also of concern for the very severe environment expected at altitude. In an effort to establish the degree of concern which should be carried into design for this system a brief thermal analysis is given in Appendix B for some of the elements mentioned. The unique feature about the camera is that it will actually perform better the colder the CCD chips are kept; therefore the unit will be prechilled before launch by its ground support unit and then while on flight the thermoelectric units will be able to more than handle the heat input loads. (Note: the ground unit is a water chill loop and the lines would be drained and purged prior to launch to prevent freezing.)

Most of the gondola surfaces will be give a reflective coating to control radiation heating while in flight. The batteries will be insulated and consideration will be given to insulating some of the other key electronic units to prevent temperatures going below the lower limit of any of the electronic elements in the package. The optical filters will be given a specific design heat transfer path to allow heater control to maintain a given operational temperature set point. The optics box enclosure and the telescope tube will\probably be built out of graphite - epoxy for flight. There are techniques in the method of layup for such structures to make the thermal expansion zero. Lense holders will also be carefully designed to prevent thermal distortion or lense motion due to temperature changes.

TABLE 2

EXVM BALLOON MISSION POWER SYSTEM LOAD ESTIMATE

Voltage	Item	Load (watts)
28 VDC Loads:	Charge Regulator	10.0
	28v Regulator Loss	87.0
	Elevation Gimbal	28.0
	Rotator	28.0
	Reaction Wheel	14.0
	Linear Positioner	5.0
	Rotary Positioner	20.0
	Tracker	60.0
	Blocking Filter	15.0
	Fabry-Perot	100.0
	Secondary Mirror	80.0
	Battery Heaters	40.0
	Thermal Control Sys.	60.0
	Camera System(28v)	18.0
	Tape Recorder	15.0
	Power Conversion: +5vdc	34.0
	-5vdc	2.0
	+15vdc	20.0
	-15vdc	7.0
	28vdc Subtotal	(610.0)
+5vdc Loads:	Science Data System	20.0
	Camera System	24.0
	Balloon System Controller	40.0
	Thermal Electric Coolers	50.0
	+5vdc Subtotal	(134.0)
-5vdc Load:	Camera System	9.0
+15vdc Load:	Camera System	58.0
-15vdc Load:	Camera System	28.0
	Power Sys. Total =	872.0

3.5 VIDEO TELEMETRY

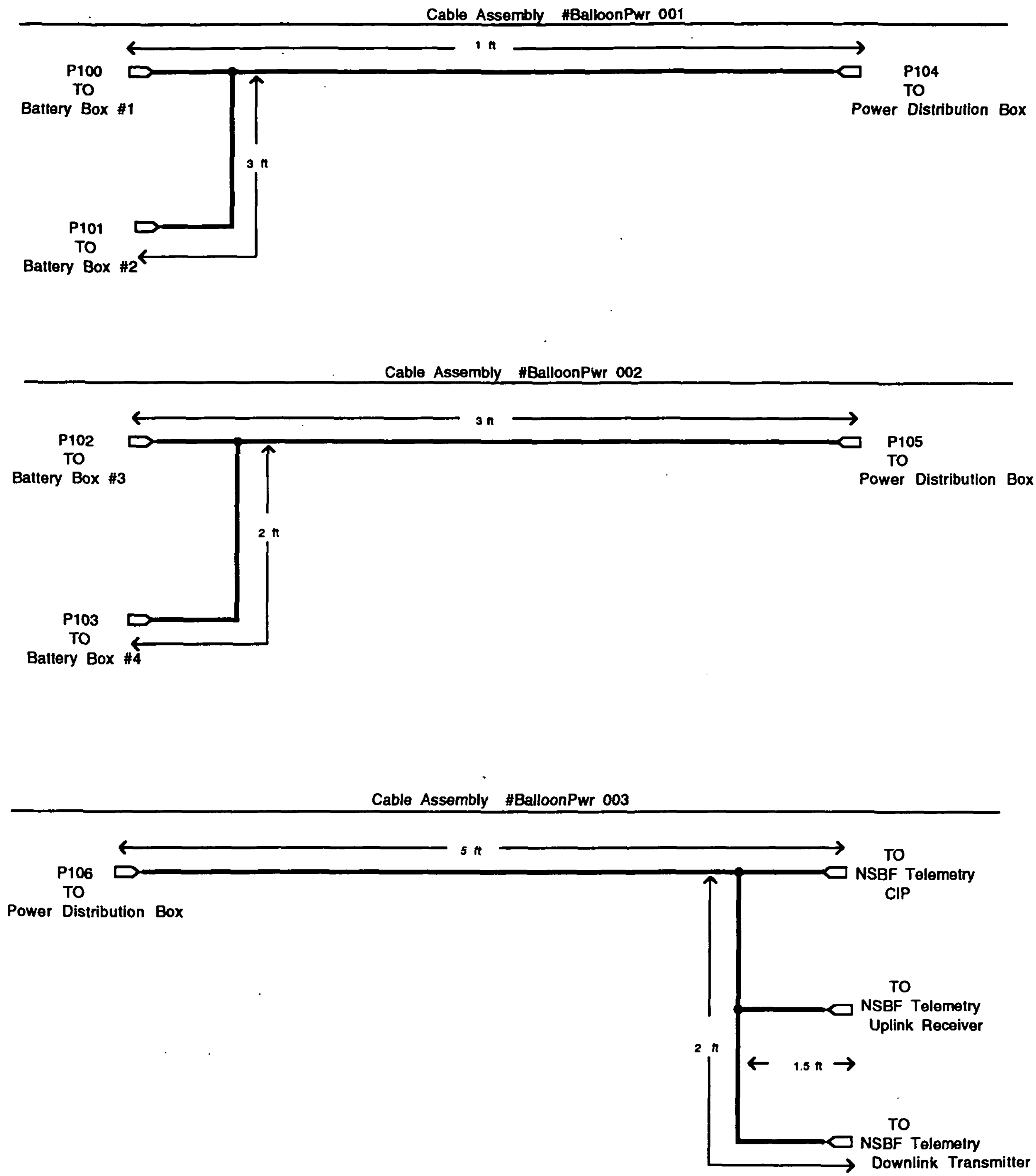
A subcontractor study of the options and proposed approach for an EXVM video telemetry link is included in Appendix C.

4.0 NSBF SUPPORT EQUIPMENT

To complete the equipment integration necessary for a balloon flight, the telemetry interface equipment shown in Figure 2 is furnished by NSBF. The CIP is a standard flight package that serves as the balloon control system and it has the encoders for interface with the up and down link telemetry systems. Ground commands to the science package will be received by the CIP and then routed to the Balloon controller for relay to the EXVM controller. The ground station telemetry transmitter and antennas are also furnished by NSBF.

APPENDIX A

INTEGRATION CABLES



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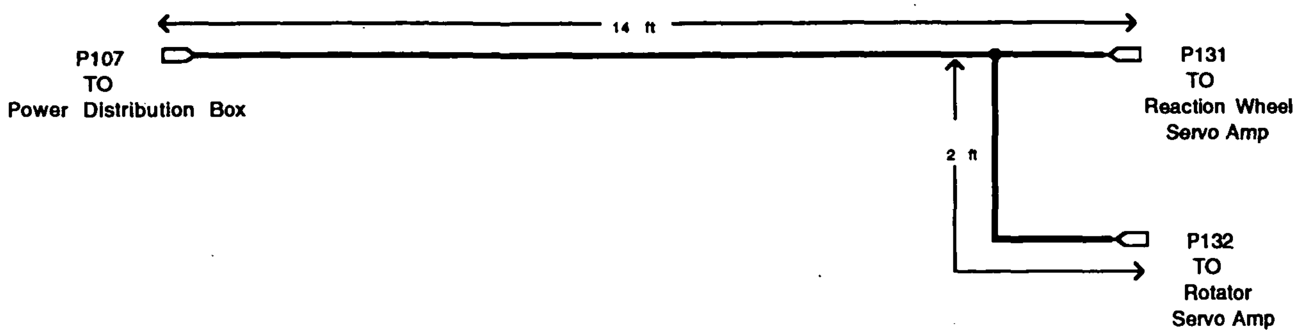
Cable Assembly #BalloonPwr 004



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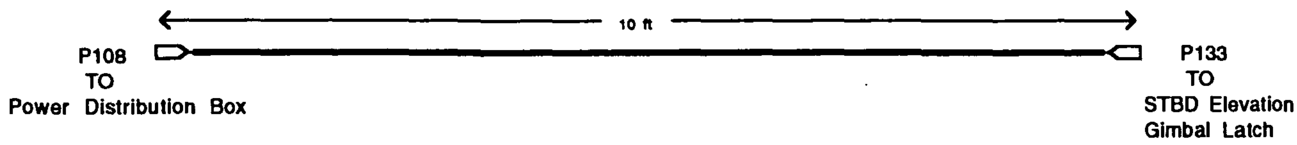
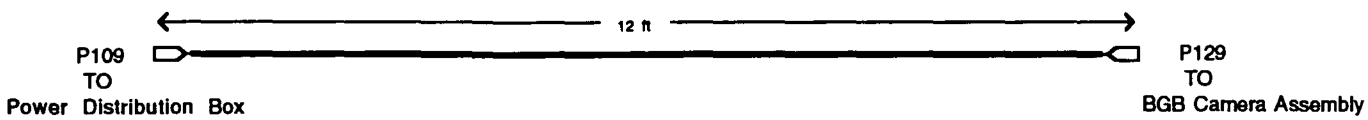
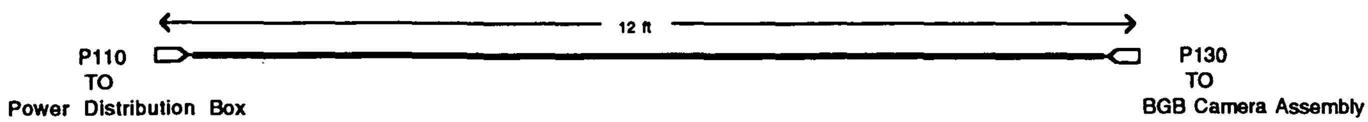


Cable Assembly #BalloonPwr 006



Cable Assembly #BalloonPwr 007



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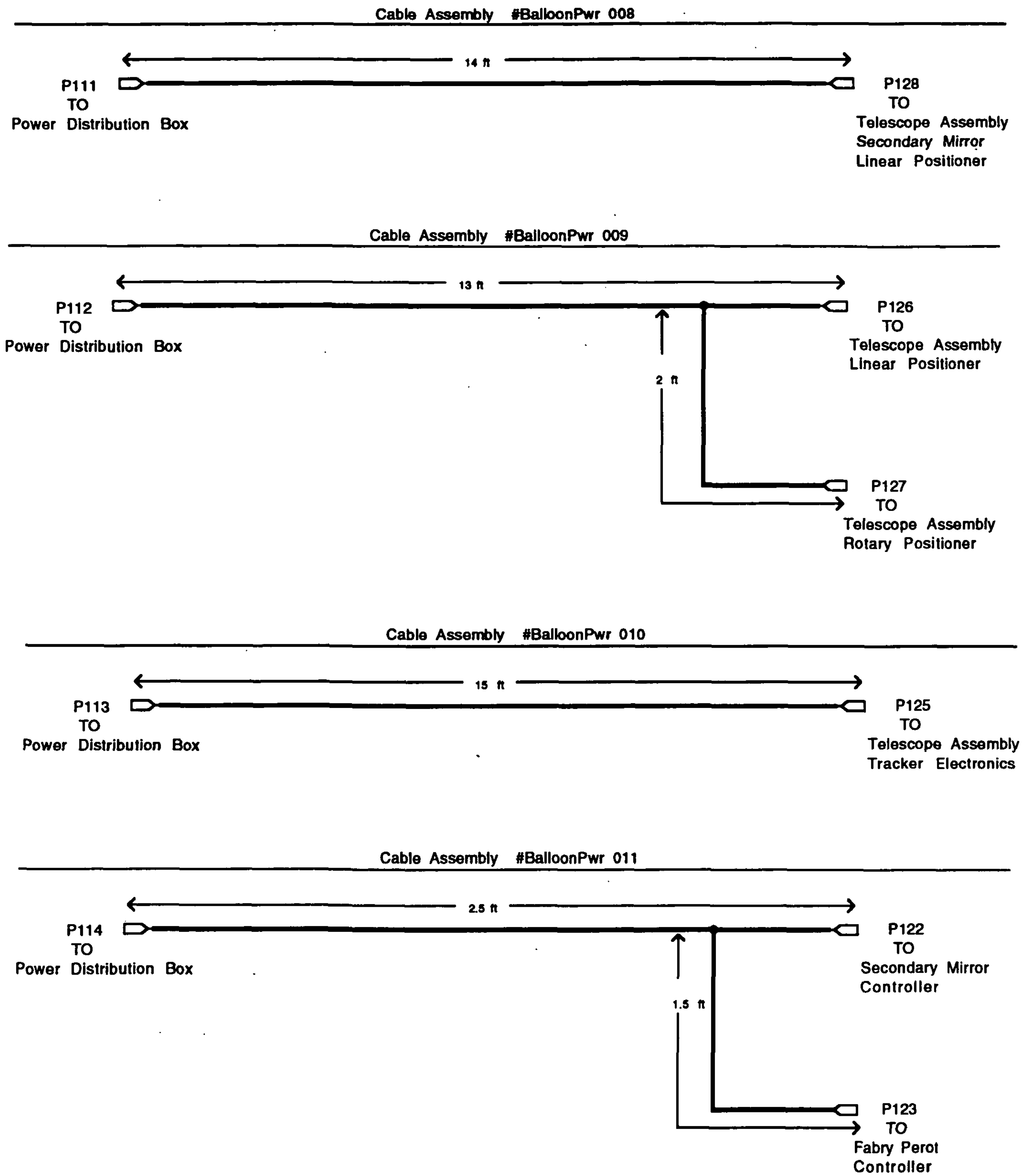

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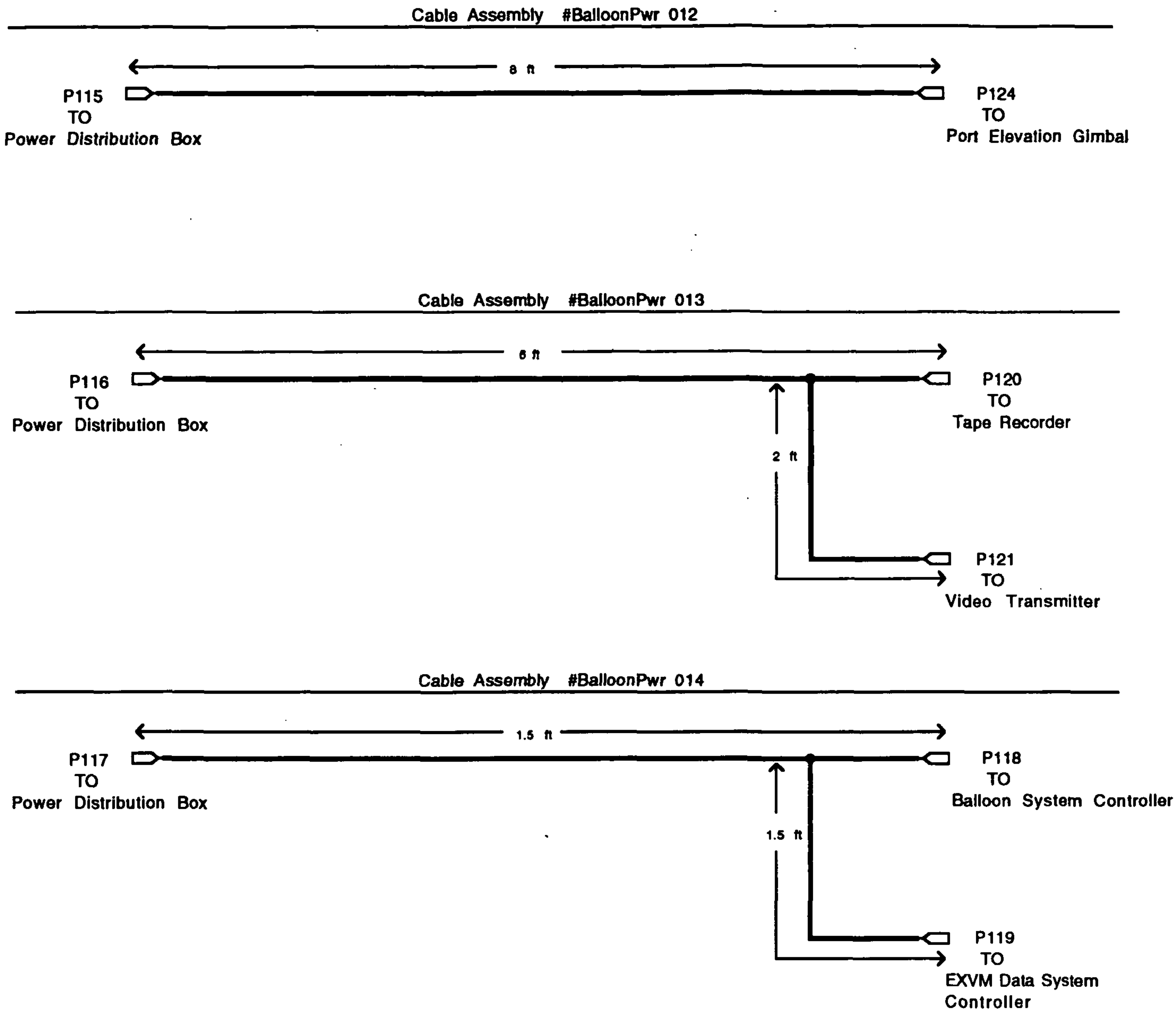

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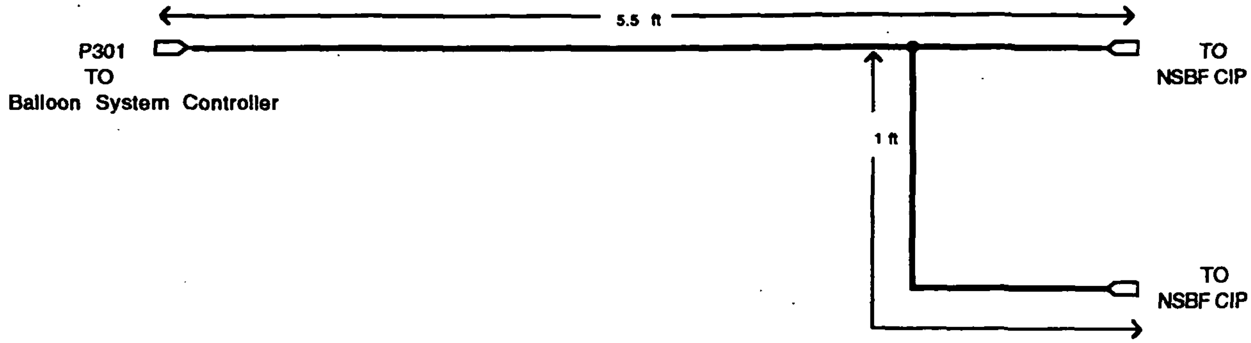
Cable Assembly #BalloonData 015



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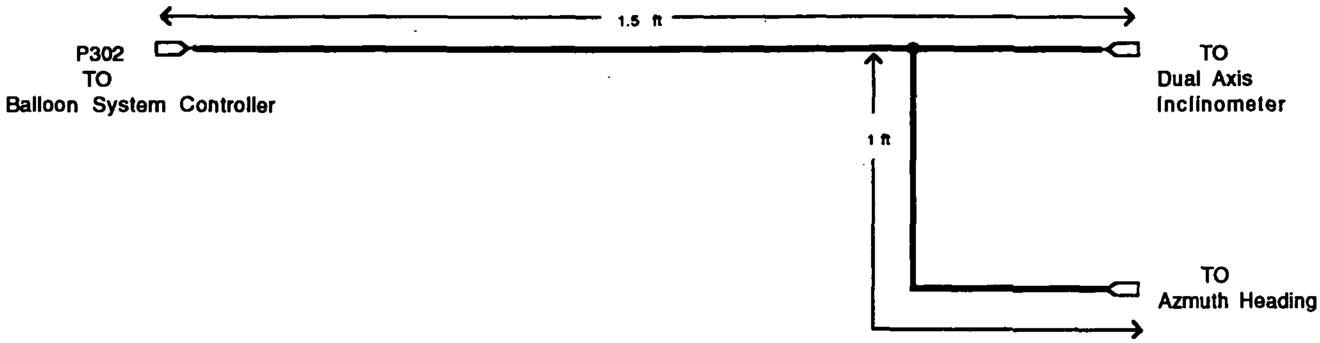

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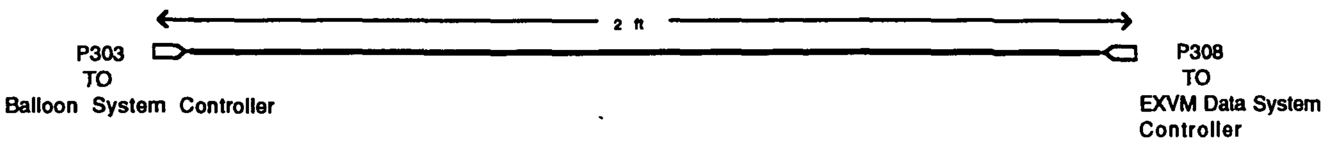

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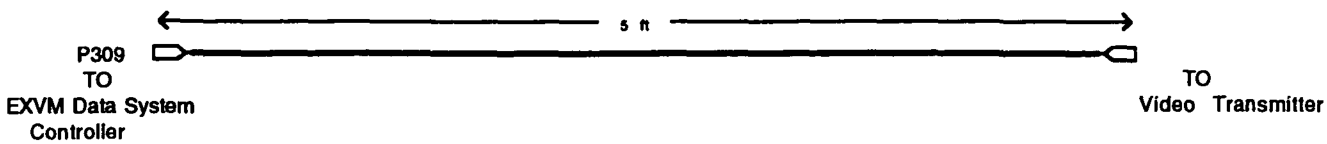

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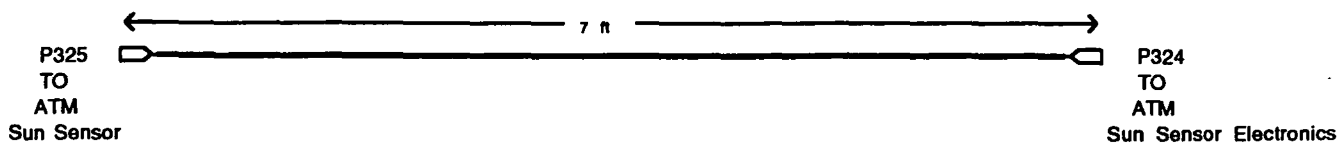

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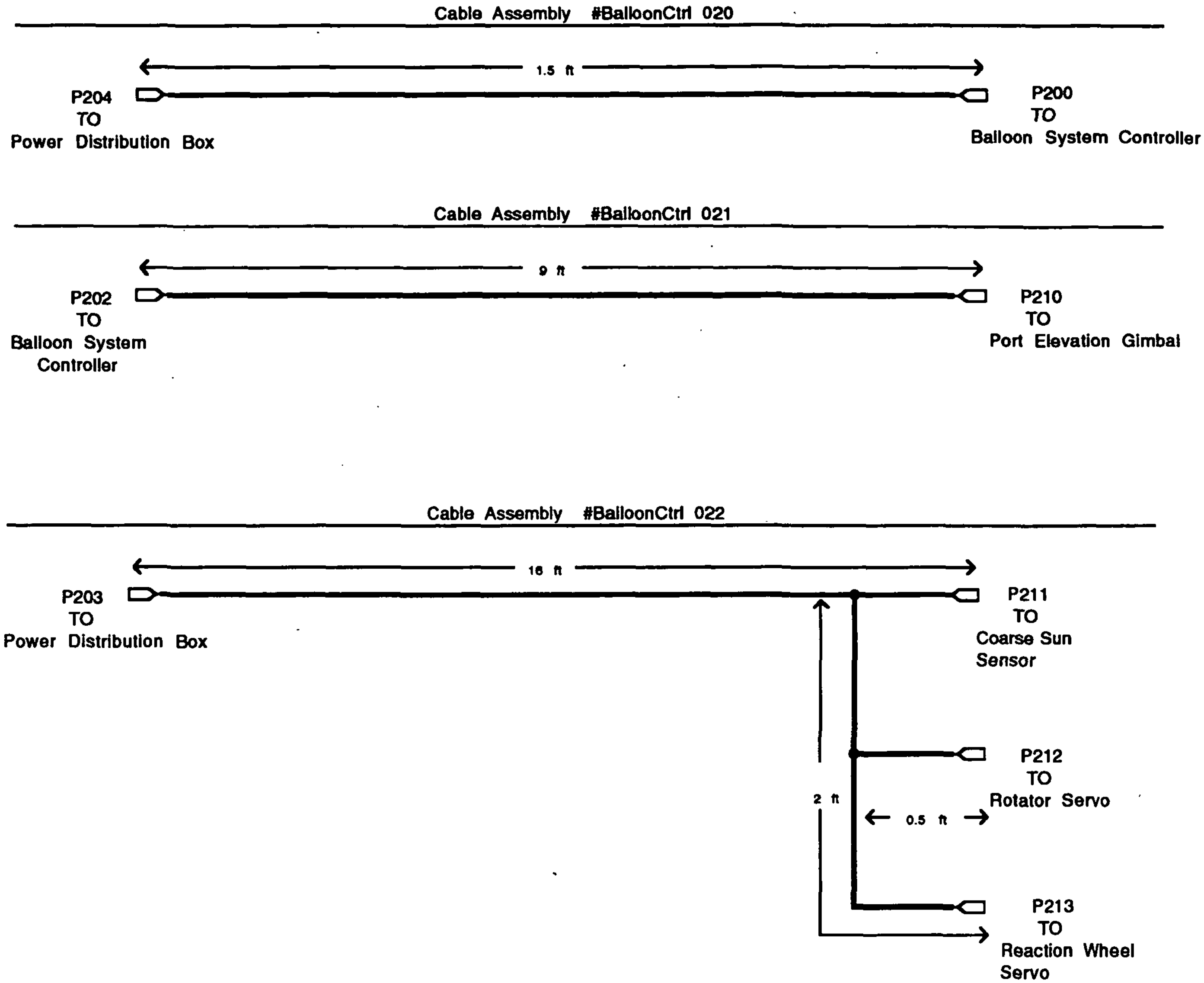

Project Title:	NASA Balloon
Page Title:	Control Cables
Orig. Date:	12/11/93
Last Mod. Date:	12/14/93
Page Number:	6 of 8
Draw by:	Wallace Davis

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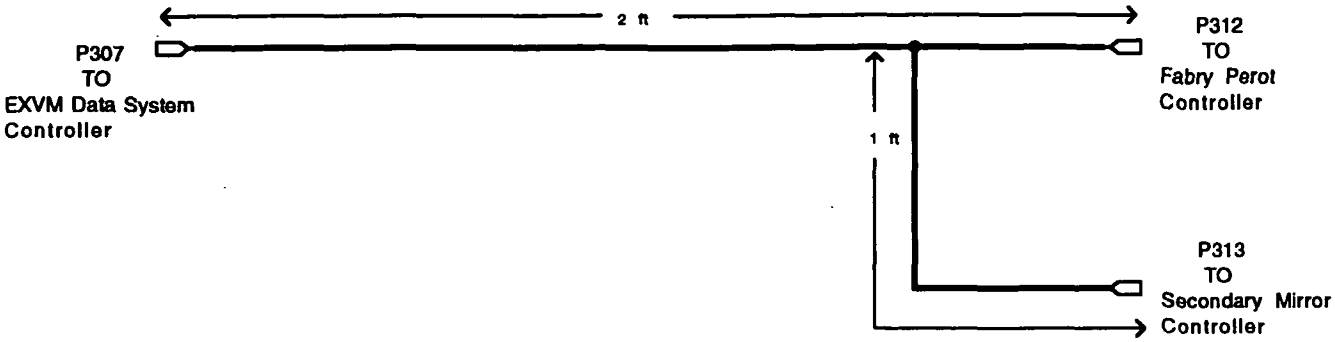
Cable Assembly #BalloonData 023



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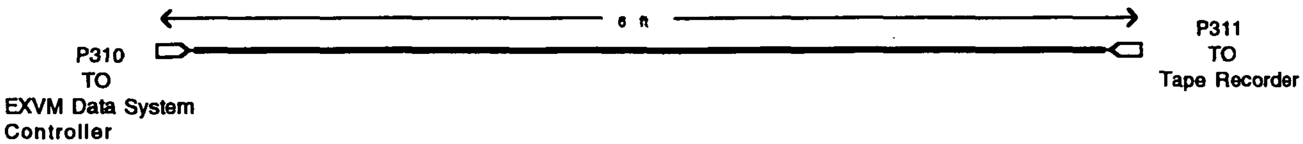

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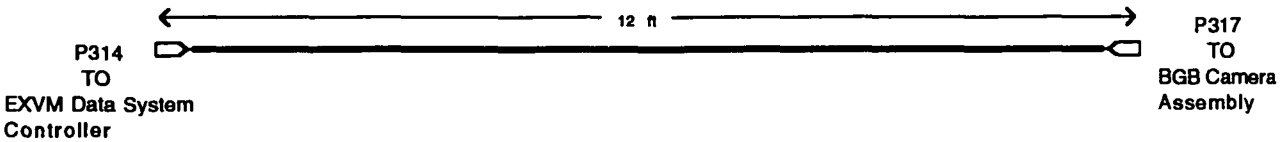
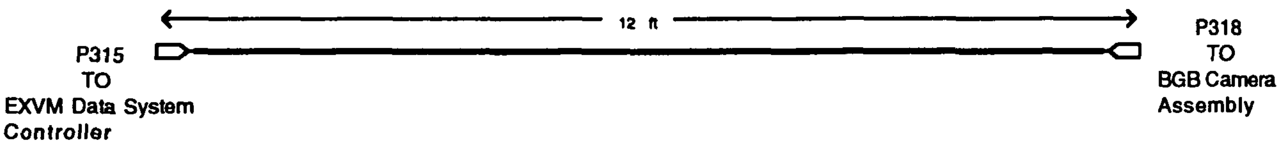
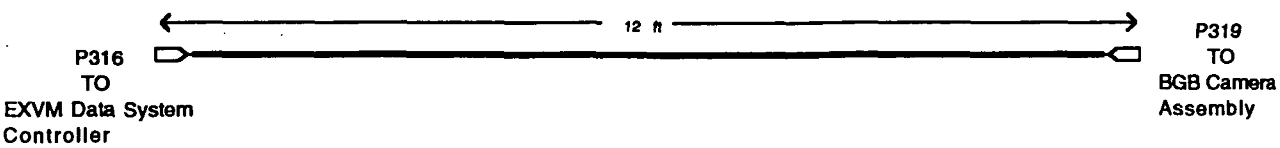


Cable Assembly #BalloonData 026



Cable Assembly #BalloonData 027



Project Title:	NASA Balloon
Page Title:	Data Cables
Orig. Date:	12/11/93
Last Mod. Date:	12/14/93
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Draw by:	Wallace Davis

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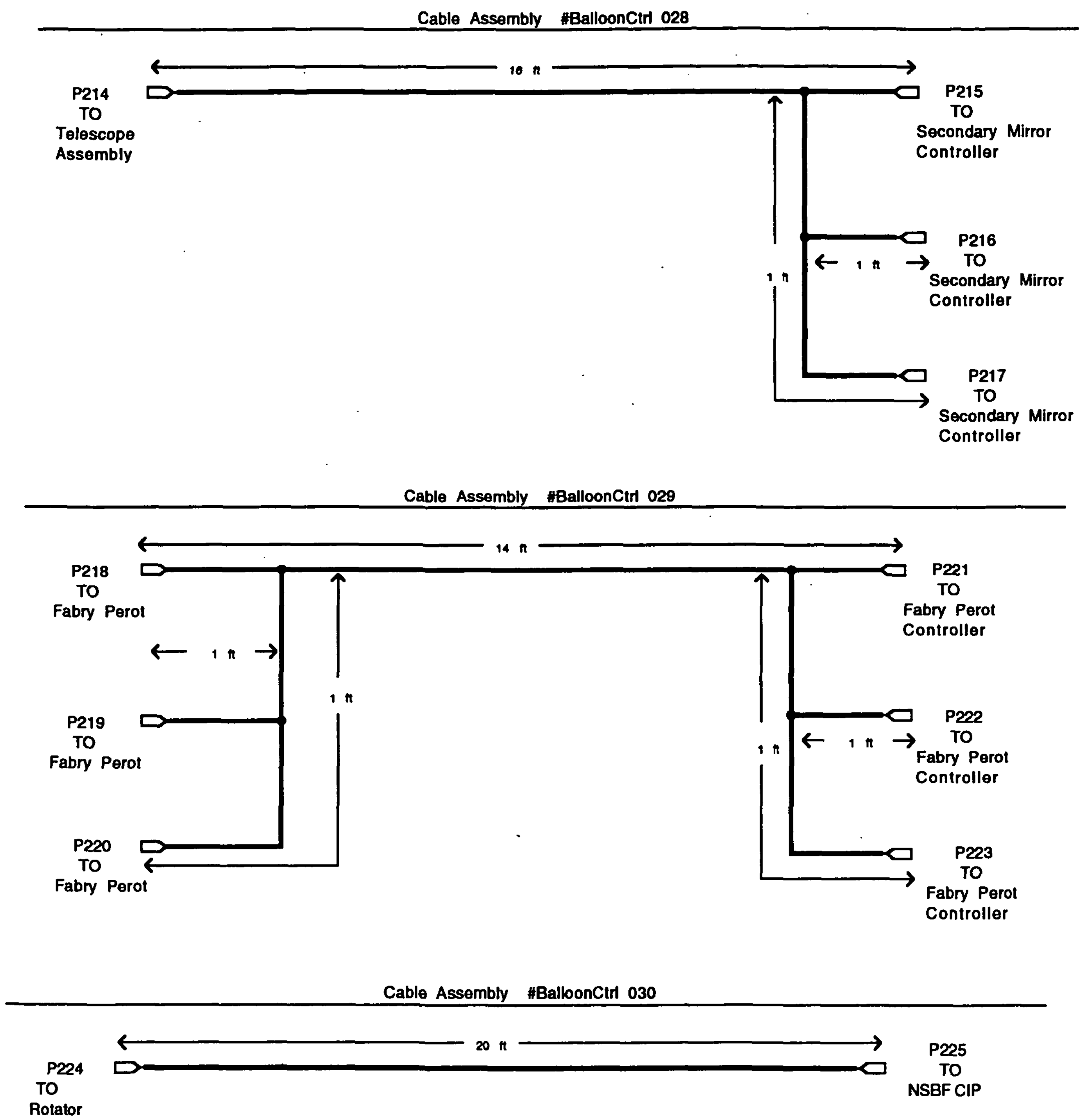

Project Title:	NASA Balloon
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APPENDIX B

THERMAL ANALYSIS

BALLOON EQUIPMENT THERMAL ASSESSMENT

The following is a brief thumb nail analysis of the EXVM thermal design issues:

1. Preferred temperature of camera assembly is near -40F to optimize efficiency of the "thermoelectric" cell

2. Preferred temperature of the Blocking filter is near 80 F biased cold so that the thermal control heater can be used to maintained the high tolerance temperature control +,- 1 F.

3. Temperature on ground is near 80 F, temperature at altitude is -51 F.

4. Due to the relatively large mass of the components involved; Blocking filter at 1.6 lbs , camera lens assembly at 10 lbs, and the total telescope at 368 lbs there is a large amount of "sensible heat" to be removed to reach the ambient sink temperature of -51 F. The mission duration of 8 hrs will make thermal time constants for this unit a primary design consideration. The time constant is predicted to be 4 to 6 hrs to reach near -40 F temperatures. Isolation from the flow of this heat out of the telescope for the camera assy and connection to the flow for the filters needs to be considered in the design.

The camera assembly is prechilled to a low temperature (no sensible heat to deal with) on the ground so the aloft cooling design for this unit need only address the conduction paths to the ambient cold sink relative to the surrounding telescope structure. The large size of the components will result in an expected large conduction path to the structure greater than 3 square inches (assumed aluminum). These paths should be biased to the cold sink. Thermal isolators at selected assembly mounting points could be used to bias the conduction path radially towards the sink and limit heat flow longitudinaly from the balance of the telescope.

The blocking and Fabry Perot filters are also expected to have relatively large conduction paths on the order of 3 square inches. The thermal design for these units needs to address the isolation from the cold sink. The level of isolation can be optimized based on the detailed design. It would be beneficial, if weight limits allow, to provide some level of thermal capacitance for the units. The added capacitance will increase the thermal time constant for the filter which will ease the temperature monitoring and control task. (Large masses with high internal conduction relative to external conduction change temperature slowly and predictably.)

6. The effects of internal lens heating from solar appears to be minimal particularly for the large masses involved as cited in the data provided. External solar loading should be minimized with external finishes ie. white paint. The 600 to 800 watts from the internal sources should be sinked away from cold loving components or to the outside to prevent heating effects.

7. Based on the assumptions of this assessment a detailed EXVM thermal design should not be difficult to make provided the issues noted are given due consideration in the structural design.

Some additional calculations for reference are enclosed.

$\frac{KA}{\Delta X}$ INTERNAL PATH $\sum \frac{117\ Btu/_{hr\,ft\,°F}(12)}{(12''/2)}\left(\frac{3}{144}\right) \cong 5\ BTU/_{°F\,Hr}$

h_e external surface 2.0 Btu/hr °F ft² $\quad A \approx \frac{47+23}{2} = 35\ ft$

h_o internal surfaces 1.0 "

U internal $\frac{1}{\frac{1}{h_oA}+\frac{\Delta X}{KA}+\frac{1}{h_oA}} = 4.0\ Btu/_{hr\,°F}$

Using Transient relationship for internal conductance of 4 Btu/hr °F $\quad U_K \approx 192$

$K_s/h_c\ \frac{6}{12} = 192$ unitless $\quad a = \frac{k}{c_p} = \frac{192}{.2(170)} = 5.6$

$\frac{T_\theta - T_\infty}{T_i - T_\infty} \quad \frac{420-410}{540-410} = .077$

$\frac{\partial\theta}{r_o^2} = 140^*$ $\boxed{\theta = 6.2\ hrs}$ To reach $-40\,°F$

This methodology is crude but for a rough estimate the results should be close enough to predict order of magnitude time constant. Solar loading will increase time to cool however reflective COATINGS ANTICIPATED will reduce this effect.

* KREITH PG 171

BATTERY ASSESSMENT

Assumptions

1. Convection $h \approx 2\ ^{Btu}/_{hr\,ft^2\,°F}$ so K is limiting factor
2. Temp at altitude 100,000 ft −51 °F
3. Battery(s) is insulated 120 lbs Total

Results

1. Final Battery temperature is shown for various insulation values equal to 1 or 2 inches of Foam or glass wool and various Battery efficiencies.
2. Worst case analysis shows that even at high efficiencies and 600 w power utilization Battery will maintain suitable operational temperatures.
3. Optimization of insulation thickness, Battery sizing for power draw, and system weight can be performed to design 8 hr operational system at minimal weight.

Heat loss from Battery over 8 hrs equals Temp drop of Battery.

$$M c \Delta T_B = \frac{KA}{\Delta X}(T_B - T_a)\,8\,hrs$$

$K = .025$ Btu / ft hr °F

Battery 10" X 12" X 24" $A = 9ft^2$

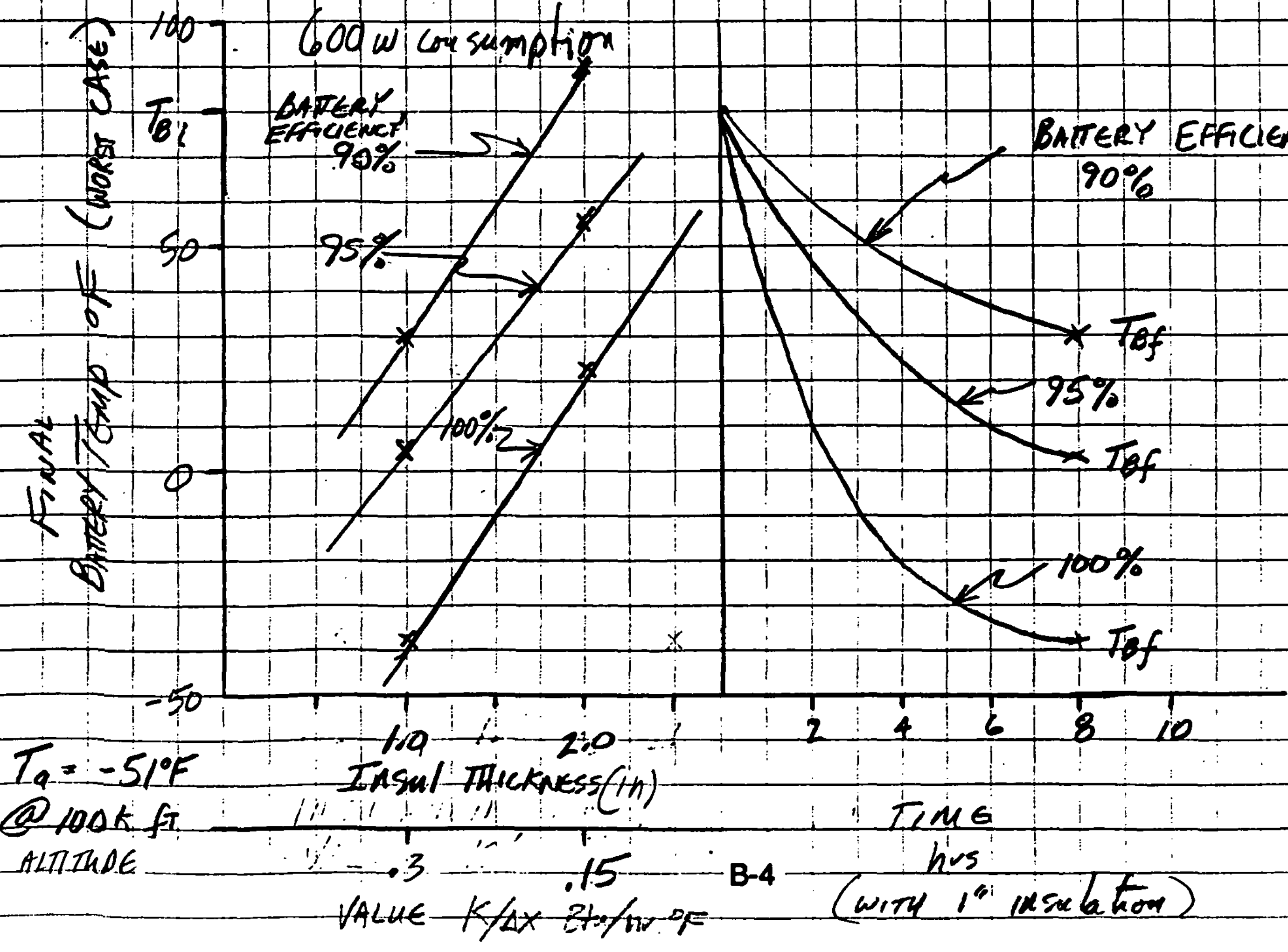
$M = 120$ LBs of Battery

$C = .2$ Btu/LB °F

$$120\,LB_m\ .2\ Btu/LB_m\,°F\ \Delta T_B = .025\,Btu / hr\,ft\,°F\ \frac{(9ft^2)}{(1in)}[80-(-51)]°F\ 8hr$$

$\Delta T_B = 117.9$

T_B final = -38°F NO POWER USAGE



$T_a = -51°F$ @ 100K ft. ALTITUDE

APPENDIX C

VIDEO TELEMETRY STUDY

Applied Research, Inc.

Corporate Headquarters:
6700 Odyssey Drive • Research Park West
Huntsville, Alabama 35806 • (205) 922-8600
P.O. Box 11220 • Huntsville, Alabama 35814-1220
FAX (205) 922-8601

October 29, 1993

Teledyne Brown Engineering
Att: Ms. Jackie Hicks, MS25
Cummings Research Park
300 Sparkman Drive NW
Huntsville, AL 35805

Dear Ms. Hicks:

Enclosed is our letter report documenting the results for a Video Telemetry System Concept study under Purchase Order #820375.

This study covers information gained from a review of customer requirements for a communication system to support operation of a *Solar Magnetograph* (EXVM). It recommends a cost conservative method of integrating existing ground equipment with flight components for digital telemetry, conventional analog video and a consideration for digitally compressed video transmission.

Sincerely,

Tom Barr

Tom Barr
Senior Engineer
Applied Research Inc.

1700 NORTH MOORE • SUITE 1520 • ARLINGTON, VIRGINIA 22209 • (703) 243-8448

LETTER REPORT FOR EXVM COMMUNICATIONS

1.0 REQUIREMENTS

1.1 Operating Range to be 300 miles Maximum

Initial launch of the Magnetograph will be from Palestine, Texas. Launch season will be selected for minimum drift, thus balloon should remain stationary over the launch point at a float elevation of 80 to 100 k feet. For assurance of continuous contact the maximum design range of the up and down link has been set at 300 miles. For a normal minimum drift flight the slant range will be about 40 miles. At a range of 300 miles the elevation angle is approximately 3.6 degrees. At angles of less than this poor data quality may result. Using a 300 miles design range further assures communications regardless of launch location.

1.2 Telemetry (Downlink Analog Data)

A maximum of 30 analog channels will be required to monitor magnetograph operation. Examples are battery voltage, current, temperature, atmospheric pressures and similar slow changing measurements. Inputs to the telemetry system will be provided by conventional signal conditioning amplifiers, voltage dividers and digital to analog converters. Inputs will be scaled to ± 2.5 V standard for all channels.

1.3 Logic Commands

Logic or on-off commands are required in both the forward and return links. Between 32 to 48 independent commands will be used for control of the Magnetograph telescope and a equal number for flags that the command was received and enabled. For example, it may be desired to command the unlatch of the telescope and then downlink the signal to indicate that the command was carried out.

1.4 Uplink Analog Signals

No requirement was identified for uplink analog signals. This function may be done using groups (8 bits) of logic commands to control a digital to analog converter to output a voltage.

1.5 Video Signals

A downlink video signal from the magnetograph of 1024 x 2048 element image sensor is required. Each pixel will be encoded to 256 gray levels (8 bits). Total bit content per picture is 16.8 Mbits. To focus the telescope, all or selected, portions of the image array are to be transmitted to the ground control station. Additionally it is desired to transmit the entire image array to the ground for real time evaluation of the telescope performance.

1.6 Ground Station Location

The primary ground station will be located at the National Science Balloon Facility (NSBF).

2.0 EXISTING FACILITIES

2.1 Instrumentation Stations Exist at the NSBF Facilities

The Palestine, Texas station is equipped with two 6 foot remote controlled dish antennas for the down links at 1400 to 1800 MHz. The noise figure of this antenna is 1dB. A uplink transmitter operating at 138.54 MHz with 40 W output provides up to 96 logic functions. Of the 96 logic outputs 48 are available for EXVM. These outputs are open collector and will drive a 200 mA load. The uplink receiver has a noise figure of about 7 dB.

The telemetry downlink has 12 subcarrier channels available. These are IRIG standard subcarriers HH(30%), E(15%), V(15%), 12, 11, 10, 9, 8, 7, 5, 3 and 1 of 7.5% deviation. Subcarriers E, 12, 10 and 5 are reserved for NSBF balloon monitor functions, the remaining are available for the telescope. The telemetry transmitter operates in the 1435 to 1540 MHz band with 2 Watts output.

NSBF can supply a video transmitter. This transmitter operates at 1771 MHz with a 6 MHz RF bandwidth and power output of 2 Watts. Modulation is linear FM. The baseband input data capability of this transmitter is about 1.5 MHz.

NSBF (Palestine) has a full complement of standard telemetry receiving, recording and decoding equipment. Shared operation of facilities is cost effective and encouraged by NSBF personnel. Information on NSBF telemetry facilities was provided by Mr. John Sparling (903) 723-8047.

3.0 APPROACH

For the EXVM program several approaches for the datalink design are considered. The most costly is to provide a complete and independent up and down telemetry and datalink for the gondola. This includes an independent ground station and recording facilities. A conservative estimate of the cost of a EXVM portable ground station is about $200K (including vehicle). Cost of flight equipment will be $35 to $45K. Details about cost of components are covered elsewhere in the memo.

A second approach is to provide all the flight data and telemetry equipment and use the NSBF ground station. This will save the cost of the $200K ground station. However, it inferred the need of additional ground

station receivers and decoders with a potential cost of about $70K ($20K for receivers, $25K for PCM decomutation equipment and $20K for a subcarrier decomutator and uplink transmitter). Additionally, since more RF links (2 to 3) are involved, there will be a greater chance for mutual RF interference between link and the difficulty of getting authorization for the new frequencies.

The most conservative approach is to use the equipment provided by NSBF and add only components not otherwise available. This would be the wideband video downlink. Assuming a launch from Palestine during the stationary wind period a chase vehicle will not be required.

In summary the RF link structure for the conservative (recommended) approach is a follows:

Link Function	Frequency	Component Source Ground	Component Source Airborne
Uplink commands, 48 EXVM channels	138.54 MHz	NSBF	NSBF
Downlink telemetry (7 subcarriers)	1435 MHz	NSBF	NSBF
Gondola TM PCM multiplexer, 48 ch.	Baseband	NSBF	EXVM
Video downlink, 4 MHz baseband	1475 MHz	EXVM	EXVM

4.0 RECOMMENDED EXVM COMMUNICATION SYSTEM

4.1 Uplink Commands

This link will use the existing NSBF 138.54 MHz channel, ground transmitter and gondola logic decoder. Forty-eight (48) logic lines will be made available to the EXVM electronics. It is recommended that the logic pull-up resistor be about 1000 ohms and be sourced to a +5 Volt supply. To avoid current loops and transients it is suggested the +5 V and logic return be provided by and be common only to the NSBF decoder. A buffer interface between the decoder and other EXVM logic is recommended. A opto-coupler would be ideal. A standard computer interface at the ground station is available. Coding sequences, latch enable/disable features when linking commands must be furnished by EXVM ground equipment and software.

4.2 Analog Telemetry Downlink

For simplicity and good amplitude accuracy a Pulse Code Modulated (PCM) analog telemetry system is recommended. This will consist of a 8 bit A/D converter with a 48 channel input multiplexer. The A/D output is in a serial format and configured for a non-return-to-zero output. Two channels will be hard-wired to form a frame synchronization pulse of two 8 bit non changing words. Since two of the 48 channels are devoted to synchronization only 46

channels are available for data. The encoder output (serial bit stream) is then sent to the existing NSBF subcarrier assembly. The composite output of the subcarrier then FM modulates the transmitter with a baseband signal that now contains the balloon data and EXVM data on independent subcarriers. Subcarrier channel HH has a center frequency of 165 kHz and can be modulated ±30% of center frequency. Therefore a maximum sampling rate for the encoder will be 99 ks/s.

The sample rate for each channel will be fs=99k/(number of bits * number of channels) or 272 samples/s. This will allow a maximum (single channel) input sinewave frequency to be 272/2 or 136 Hz. Since it is rare that a measuring voltage is a sine wave the more practical input frequency will be about 1/4 of this value of 34 Hz. All analog inputs to the encoder must be scaled to ±2.5 Volts full scale.

Referring to Figure 1 (EXVM Communication System) the encoder will be mounted on the EXVM telescope body as close as possible to the various analog measuring inputs. The encoder output will be routed to the NSBF subcarrier assembly via a shielded twisted wire pair. By doing the encoding close to the magnetograph measurement inputs the chance of ground loops or DC offset is greatly reduced.

The FM modulated signal is transmitted to a ground receiver antenna, RF subcarrier demodulated and then decommutated to output the original 46 analog data channels. The signals can be displayed on a strip chart recorder and stored on magnetic tape. The components unique to the EXVM for analog telemetry will be the 48 channel encoder, ground station subcarrier demodulator and PCM decommutator. The transmitter, antenna, ground receivers and ground antenna are all standard components furnished by NSBF for balloon operation.

4.3 EXVM Video Transmission

Digital video rates from the EXVM 1024 x 2048 element video array cannot be sent to the ground station in a continuous serial format because the high data rate will exceed the capacity of a reasonable cost transmitter. For a practical and cost effective design the equivalent analog data rate for ordinary broadcast TV must be provided. For the EXVM application this limit is about 4 MHz. The FM modulation process spreads the baseband video input by a factor of 4 and therefore the highest input frequency cannot be much higher than 4 or 5 MHz to stay within the maximum authorized channel band of 20 MHz. This wide bandwidth from the FM process results in a modulation improvement factor of about 12 dB. The 12 dB gain allows the use of a much smaller transmitter size. For example, without this improvement factor it will take a transmitter of 80 watts output compared to the 5 watts recommended. A second reason for limiting the analog bandwidth to 4 MHz is the availability of instrumentation grade transmitters. Many vendors have standard transmitters with bandwidth up to 6 MHz that are designed for video transmission. For units of greater

bandwidth the cost will rise sharply and it will be very difficult to obtain frequency authorization.

4.4 Video Data Format

The most straight forward mode of transmission using the 4 MHz bandwidth transmitter is to convert it to a analog signal with a D/A converter and transmit it to the ground. At the ground station the image is displayed using a monitor. The scan rate and format are not critical to the analog transmission process. Several non-standard scan monitors are available. The only restriction is that the final output of the D/A converter must be bandwidth limited to 4 MHz with a low pass filter. Obviously there is no gain by high speed digitization of a large array of image elements if the resultant components exceed the bandwidth of the transmitter. The limitation of analog transmission is that the ground station video signal to noise ratio should exceed about 40 dB to reduce the disturbance of visual noise and the loss of absolute amplitude accuracy that is inherent in the original image.

If an all digital transmission system is desired or if more resolution is needed than is available from a conventional analog system then an image compression system should be considered. Image compression may be done on an all digital basis to reduce the transmission bit rate for a given configuration. The block diagram, Figure 1 shows an alternate route for the video to pass through a JPEG video compression device. The JPEG output is then modulated on the transmitter by a digital modulator attached to the transmitter input. At the ground receiver the output is digitally decoded and processed by a JPEG decompressor and displayed.

JPEG compression/de-compression has significant advantages of reducing transmission data bandwidth. It will require the addition of processors both airborne and ground. JPEG processing may be done using conventional computers or specialized chipsets. Section 8.0 covers details of video compression techniques.

5.0 Antennas and Signal Margins

To maintain a good video downlink signal over the maximum expected range of 300 miles, some gain in the gondola antennas will be necessary. For continuous contact five antennas are recommended. Four of the antennas are to be mounted on each of the lower sides of the gondola and angled downward 22 degrees. The fifth antenna will be pointed directly down and mounted on the bottom of the gondola. The video transmitter output is routed through a RF switch that is remotely controlled. Ground commands will then select the antenna with the best view of the station. Each antenna will have a worst case gain of 8 dB with a E and H plane beam width of 45 degrees. An example of this type of antenna is a 1 foot diameter parabolic dish. Other antenna designs are possible, for example a corner reflector. As a special note, it is possible that a single monopole stub (short stub on a ground plane about 2 feet square) will

suffice instead of the multiple antennas. This issue cannot be resolved until the exact data rate and modulation method are determined.

Signal Margin (analog system, no compression):

Transmitter Power	5 Watts
Gondola Antenna Gain	8 dB
Receiver Antenna Gain	27 dB
Gondola Cable Loss	1 dB
Receiver Cable Loss	0.2 dB
RF Bandwidth	20 MHz
System Noise Temperature	100 deg K
RF Frequency	1771 MHz

Calculated Carrier to Noise Ratio at 300 mi(480 km) = 25dB
Calculated Received Signal Level = 81 dBm

Video Signal to Noise

Carrier to Noise Ratio	25 dB
Peak Carrier Deviation	6 MHz
Maximum Modulation Frequency	4 MHz
Demodulation Filter Bandwidth	4 MHz
Receiver Noise Bandwidth	20 MHz
Improvement Factor	12.8 dB
Luminance Conversion Factor	0.0 dB (still picture, no eye integration).

Calculated Video Peak Signal to Noise = 50dB
(from Radio System Design by Freeman)

6.0 RECOMMENDED COMMUNICATION SYSTEM

The recommended communication system for EXVM is depicted in the block diagram layout of Figure 1. It will share some of the airborne and ground components with the balloon launch agency NSBF. Uplink commands will originate from a computer via a RS232 line, are processed and sent to the gondola over a 138.4 MHz link and decoded. The decoded commands then are passed to the EXVM via a opto-coupler. The TM analog signals are encoded with a 48 channel encoder and passed to the ground station over a subcarrier. Video is processed and transmitted to the ground using a 5 Watt FM transmitter operating at 1425 MHz or alternate frequency of 1700 to 1800 MHz. All components for the video link must be furnished by EXVM, only the 6 foot ground antenna is common. Five gondola antennas are required to maintain good signal. Ground station commands are necessary to switch antennas.

7.0 COMPONENT COST (MAJOR ITEMS)

See attachement for selected vendor data sheets.

7.1 <u>Video Transmitter</u>

5 Watt, 1771 MHz, $3900 to $5500

Southern California Microwave, (619) 670-3414

Broadcast Microwave Services, Inc. (619) 560-8601

Loral Conic, (619) 279-0411

Semco RF Products, (619) 438-8280

7.2 <u>Video Receivers</u>

Wide bandwidth, $4000 to $6500

Southern California Microwave, (619) 670-3414

Broadcast Microwave Services, Inc. (619) 560-8601

Loral Conic, (619) 279-0411

Semco RF Products, (619) 438-8280

7.3 <u>PCM 48 Channel Encoders</u>

$5000 to $5500

Microcom Corporation, (215) 441-6300

7.4 <u>Digital Modulator & Demodulator</u>

$4000 to $9000

Specialized device, requires design. Vendor TBD.

7.5 <u>Opto Isolator</u>

$1500 to $3000

Vendor unknown, may require local fabrication.

7.6 Antenna

$1200 to $5000

UB Corporation, (813) 876-1463

Haigh-Farr, Inc., Woburn, Mass.

Andrew Corp., Chicago

8.0 IMAGE COMPRESSION

Large amounts of data are required to produce digital images. For example, a 1024 X 1024 image with 10 bits of resolution (1024 gray levels) requires 1073741824 bits (1 Gbits) of storage space. These large amounts of data make storage and transmission of digital images almost impractical. Image compression can be used to reduce the amount of data needed to represent an image; allowing more practical storage and transmission requirements.

There are two categories of image compression: Lossless and Lossy. For applications were loss of data is undesirable, a lossless compression method should be used. With lossless compression, all information in the image is preserved. Current error free compression methods can provide compression ratios ranging from 2:1 to 10:1, depending on the image content (Lossless compression of monochrome images seldom results in more than a 3:1 reduction in code). Lossless techniques reduce image size by reducing inter pixel redundancies and coding redundancies of the image. For applications that are not sensitive to data loss, a lossy compression can be used to achieve higher compression ratios. With lossy compression, the decompressed image would differ from the actual image. This difference will result in image degradation (which may or may not be visually apparent). If this degradation can be tolerated, the increase in compression can be significant. Current lossy compression methods can provide compression ratios from 10:1 to 100:1, depending on image content and allowable degradation. Many lossy compression techniques can provide images that are virtually indistinguishable from the originals at compression's ratios of 10:1 to 20:1. Lossy compression methods take on a wide variety of techniques (such as image subsampling, lowering resolution, image transformation and quantization, and motion prediction).

To see the effects of image compression on storage and transmission of a digital image, let's consider an example. A 256 X 256 image containing 8-bits of resolution (256 gray levels) will occupy 524288 bits. At a transmission rate of 1 Mbits/second it will take approximately 0.5 seconds to transmit the digital image. If the image were compressed using a lossless compression routine that provided a compression ratio of 2:1, the image would occupy 262144 bits

and could be transmitted in approximately 0.25 seconds. Using a lossy compression that provided a 10:1 compression rate would allow the image to occupy only 52429 bits and be transmitted in 0.05 seconds.

There are many types of lossless compression but all are based upon reducing pixel redundancies while maintaining information content. Currently, there are three standards for performing lossy compression: JPEG (Joint Photographic Expert Group), MPEG (Motion Pictures Expert Group), and CCITT's (International Committee on Telegraph and Telephones) H.261 (aka Px64). These standards differ in encoding methods but all use a direct cosine transform (DCT) followed by spatial-frequency-dependent quantization. The JPEG standard performs a compression on a single digital image. The image size for the JPEG standard can be as great as 64K x 64K pixels. A lossless form of JPEG compression is also available. The MPEG standard performs compression on the first digital image and then uses that image as a reference for performing image differencing and motion prediction for subsequent images which are then encoded. The MPEG standard is used for real-time compression and playback of moving images. The image size for the MPEG standard is limited to 4K x 4K pixels, but recommended image size is 768 x 576 pixels or smaller. The Px64 standard was developed for video telephony and supports image sizes of either 352 x 288 pixels or 176 x 144 pixels.

Some software was developed by ARI to demonstrate the performance of a JPEG compression and decompression on an image supplied by NASA/MSFC. The software uses a baseline JPEG compression routine to compress and decompress the image. A factor to control the compression ratio was added (Q factor). As this factor is increased, the compression ratio increases and the quality of the output decreases. This demonstration program shows that a compression ratio of 20:1 can be achieved with a virtually identical image generated at the output. The compression ratio is printed on the display along with the RMS and maximum errors obtained from the compression/decompression algorithm. To begin the program, type JPSHOW. The UP/DOWN ARROW keys adjust the Q factor, and the compression/decompression is performed when the SPACEBAR is pressed. The ESC key will exit the program. This software was developed for demonstration purposes only; it has not been optimized to achieve the best compression ratio or output quality for the input image.

Image compression software is available that performs both lossless and lossy compression on digital images. This software is available for the PC and can cost from $100 to $1000. These software compression routines perform well on still images, but are currently not capable of operating at video rates (30 frames/sec). To perform compression at video rates, hardware compressors are needed. These hardware compressors may be compression IC or digital signal processors programmed with image compression routines. Listed below are some compression/decompression hardware that are currently available.

Array Microsystems
1420 Quail Lake Loop
Colorado Springs, CO 80906
719-540-7900

Chipset capable of JPEG, MPEG, and H.261 compression of real-time video.
Price: $700 for chipset

AT&T Microelectronics, Inc.
555 Union Blvd.
Allentown, PA 18103
(800) 372-2447

Programmable video codec chipset.
Price: NA

C-Cube Microsystems
1778 McCarthy Blvd.
Milpitas, CA 95035
(408) 944-6300

JPEG chipsets and MPEG decoders
Price : $300 for JPEG chipset
$1000 for JPEG Evaluation/Development Kit (PC card)

GEC Plessey Semiconductors
Action Desk, Lenval House
Hollingworth Ct., Ashford Rd.
Maidstone, Kent ME14 5PP, UK
(793) 518510

H.261 chipset.
Price: NA

IBM Microelectronics
Somers, NY
(800) 426-0181

Adaptive Lossless Data Compression (ADLC) chip: ADLC 1-5s.
Price: $30

Integrated Information Technology Inc.
2445 Mission College Blvd.
Santa Clara, CA 95054
(408) 727-1885

Programmable video-codec chipset
Price:

Intel Corp.
2200 Mission College Blvd.
Santa Clara, CA 95052
(408) 765-8080

Video-compression processor.
Price: NA

LSI Logic
1551 McCarthy Blvd.
Milpitas, CA 95035
(408) 433-8000

JPEG chipset
Price:

SGS-Thompson Microelectronics
1000 E Bell Rd.
Phonenix, AZ 85022
(602) 867-6100

DCT processors, motion esitmators, and MPEG decoders.
Price: NA

Xing Technology Corp.
Arroyo Grande, CA
(805) 473-0145

MPEG Compression Board for PC: 320x240 image @ 30 frames/sec with NTSC input.
Price: $795

Zoran Corp.
1705 Wyatt Dr.
Santa Clara, CA 95054
(408) 986-1314

DCT processors, JPEG (lossy and lossless) chipsets.
Price: $73 for JPEG chipset

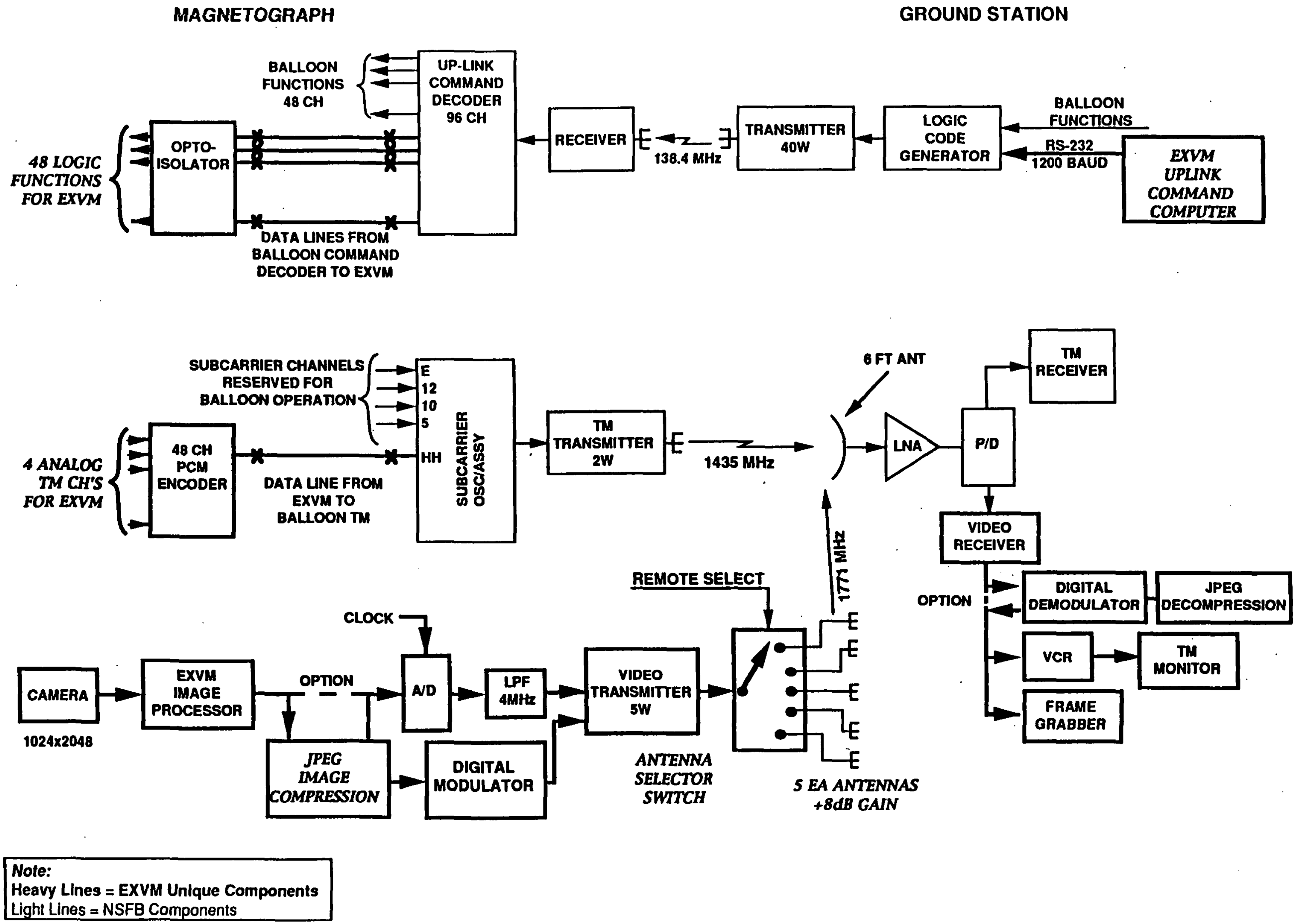


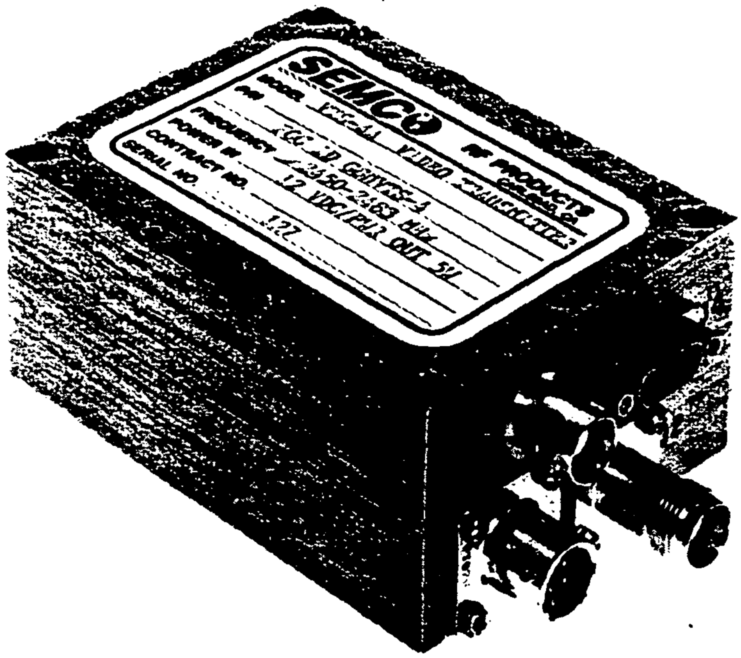
Figure 1 EXVM Communication System

with 2 subcarriers $5500

SEMCO

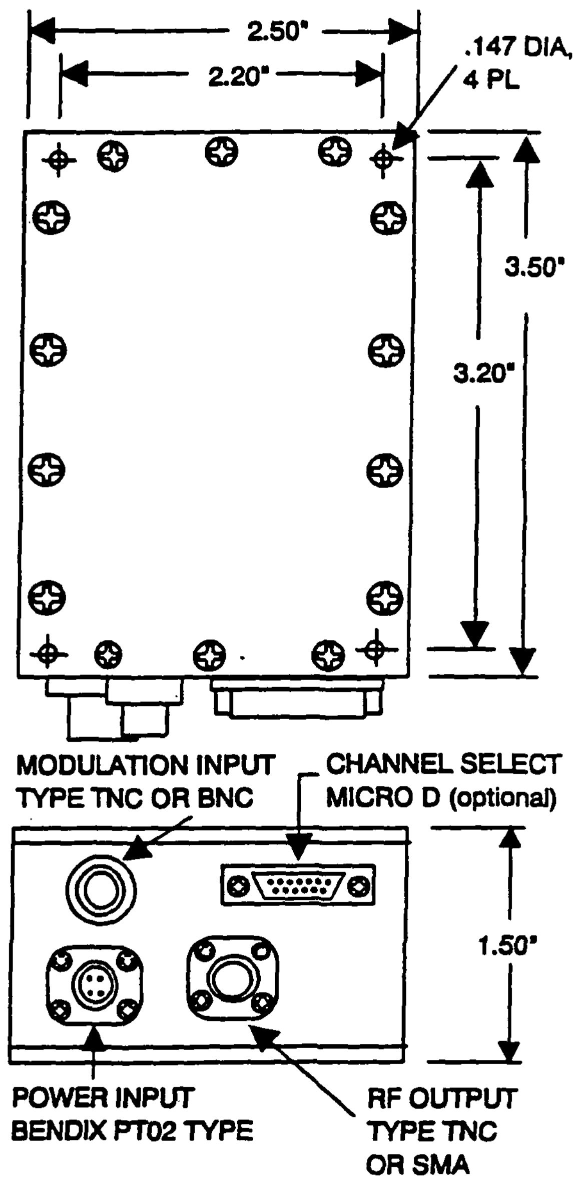
RF PRODUCTS

VIDEO TRANSMITTER SERIES VTL/VTS



FEATURES

- L-BAND/S-BAND
- 1710-1850 MHz/2200-2500 MHz
- FIXED FREQUENCY OR
- FREQUENCY AGILE
- .25-10 WATTS



DESCRIPTION

The VTL/VTS series of airborne video transmitters are designed to transmit black and white or color video signals in the frequency band of 1710-1850 MHz/2200-2500 MHz.

These transmitters are true FM, modular, all solid state and contain an output isolator that allows operation into any V.S.W.R., without damage, including open or short circuit.

Rugged construction, minimum size and weight make these transmitters ideally suited for aerospace applications where operation in extreme environmental conditions is required.

Frequency agility is achieved by utilization of a frequency synthesizer. Transmitters may be ordered as fixed frequency or any number of channels in a given band, spaced in 1 MHz increments.

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VTL/VTS SPECIFICATIONS

ELECTRICAL SPECIFICATIONS	
Frequency Range:	VTL-2: 1710-1850 MHz, fixed frequency, or up to 140 channels with 1 MHz spacing VTS-1: 2200-2500 MHz, fixed frequency, or up to 100 channels with 1 MHz spacing
Frequency Selection:	Binary, BCD, custom format or pre-wired program plug, fully TTL/CMOS compatible
Frequency Stability:	±0.005%
Output Power:	250 milliwatts, 2 watts, 5 watts, 10 watts (Customer specified)
Output Impedance:	50 ohms nominal
Spurious Emissions:	Per IRIG 106-86
MODULATION SECTION	
Type:	True FM
Input Impedance:	75 ohms nominal
Frequency Response:	10 Hz to 4.5 MHz ±1.5 dB standard, others optional to 10 MHz
Carrier Deviation:	±6 MHz peak
Deviation Sensitivity:	±4 MHz/Vp-p, factory set, adjustable
Linearity:	±2% BSL
Harmonic Distortion:	2% maximum over modulation bandwidth
Incidental AM:	2% maximum
Incidental FM:	±5 kHz maximum
Pre-Emphasis:	Per CCIR-405
Subcarrier:	Audio/TM Subcarriers available
ENVIRONMENTAL SPECIFICATIONS	
Temperature:	-20 to +70 degrees C Baseplate
Vibration:	Sine, 20 G peak, 20-2000 Hz, 3 axes
Shock:	100 G peak, 11 milliseconds, 1/2 sine, 3 axes
Acceleration:	100 G, 3 axes
Humidity:	100% non-condensing (MIL-STD-810 Method 507)
Altitude:	Unlimited
EMI-RFI:	Per IRIG 106-86 and MIL-STD-461A (3)
POWER REQUIREMENTS	
Input Voltage:	28 ±4 VDC, Reverse Polarity Protection provided (12 VDC optional)
Input Current:	3.5 amp @ 10 watts output, 1.5 amp @ 5 watts output, 1.0 amp @ 2 watts output, or .75 amp @ 250 milliwatts output
MECHANICAL	
Size:	3.5 x 2.5 x 1.5 inches
Weight:	16 ounces
Volume:	13 cubic inches
CONNECTORS	
Channel Select:	Micro Miniature D, 15 pin (multi-channel units only)
Modulation Input:	Type TNC, female (BNC option, customer specified)
Power Input:	Bendix PT02-Type, mates with MS3116E8-4S
RF Output:	Type SMA female (TNC option, customer specified)

OPTIONS

A) Extended Temperature Range
B) Audio or TM Subcarriers
C) Multi-channel Operation
D) 12 V Operation

Specifications subject to change without notice.

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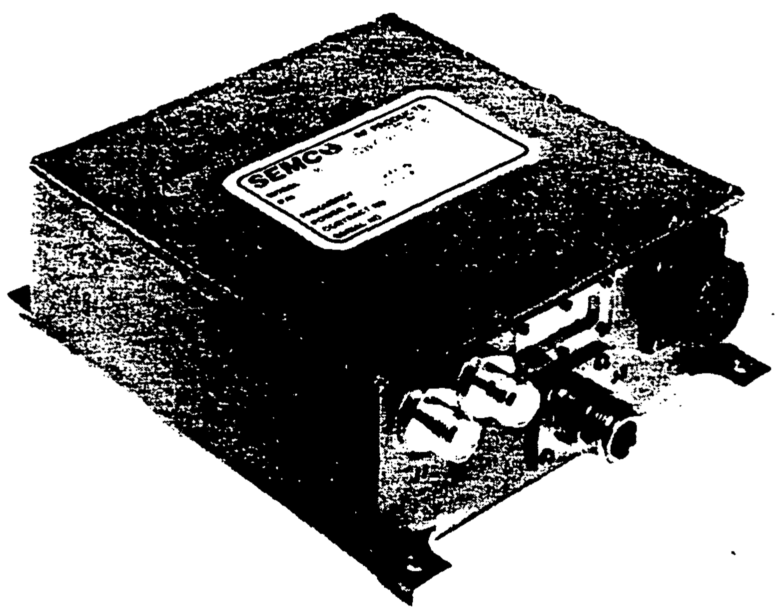
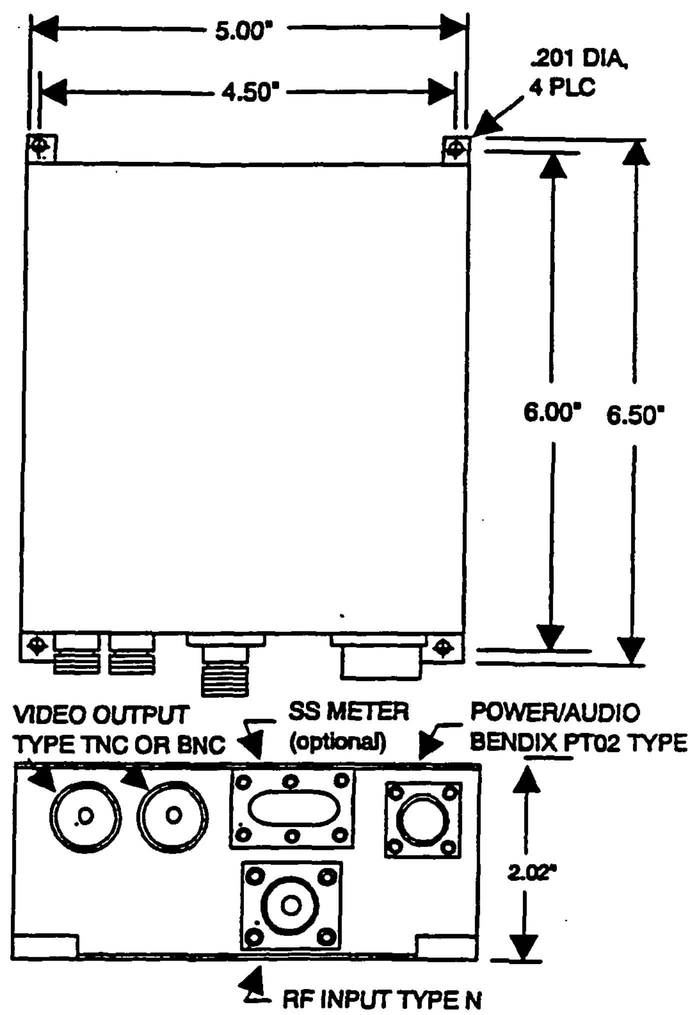
RF PRODUCTS

VIDEO RECEIVER SERIES VRL/VRS



FEATURES

- L-BAND/S-BAND
- 1710-1850 MHz/2200-2500 MHz
- FIXED FREQUENCY OR
- FREQUENCY AGILE



DESCRIPTION

The VRL/VRS series of video receivers are true FM, all solid state receivers designed for ground based reception of black and white or color video signals in the frequency band of 1710-1850 MHz or 2200-2500 MHz.

These portable receivers feature 110 VAC and 12 or 28 VDC operation for ground station or remote applications. A signal strength meter is provided to facilitate antenna alignment.

L.O. synthesis provides receiver frequency agility. Receivers may be ordered as fixed or multiple frequency units with any number of channels in a given band, spaced in 1 MHz increments.

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ELECTRICAL SPECIFICATIONS

Frequency Range:	VRL-2: 1710-1850 MHz, fixed frequency, or up to 140 channels with 1 MHz spacing VRS-2: 2200-2500 MHz, fixed frequency, or up to 100 channels with 1 MHz spacing
Frequency Selection:	Binary, BCD, custom format or pre-wired program plug, fully TTL/CMOS compatible
Frequency Stability:	±0.005%
Noise Figure:	6 dB to 9 dB depending on frequency band
Sensitivity:	-87 dBm to -84 dBm @ 20 dB S+N/N depending on frequency band
Maximum RF Input:	-10 dBm
Input Impedance:	50 ohms nominal
IF Bandwidth:	20 MHz (or customer specified)
Image Rejection:	60 dB minimum
Spurious Response Rejection:	60 dB minimum
Frequency Response:	10 Hz to 4.5 MHz ±1.5 dB standard--other BW available to 10 MHz max
Output Level:	1 Vp-p adjustable
Deviation Sensitivity:	1 Vp-p for ±4 MHz deviation
Output Impedance:	75 ohms nominal or greater than 10K ohms
Signal Level Indication:	Bar Graph (optional)
Distortion:	3% maximum over modulation bandwidth
De-Emphasis:	Per CCIR-405
Subcarrier:	Audio/TM Subcarrier available

ENVIRONMENTAL SPECIFICATIONS

Temperature:	-20 to +70 degrees C
Vibration:	Sine, 10 G peak, 20-2000 Hz, 3 axes
Shock:	20 G peak, 11 milliseconds, 1/2 sine, 3 axes
Acceleration:	100 G in each axis
Humidity:	100% non-condensing (MIL-STD-810, Method 507)
Altitude:	Unlimited

POWER REQUIREMENTS

Input Voltage:	28 ±4 VDC or 12 ±1 VDC, Reverse Polarity Protection provided
Input Current:	0.5 amp maximum

MECHANICAL

Size:	6.5 x 5.0 x 2.02 inches
Weight:	40 ounces
Volume:	66 cubic inches

CONNECTORS

RF In:	Type N
Power In/Channel Select:	Bendix PT02-Type, mates with MS3116E12-10S
Video Out:	BNC or TNC (2)
Audio Out:	BNC or Power Connector

OPTIONS

A) Extended Temperature Range
B) Audio or TM Subcarriers
C) Multi-channel Operation
D) 12 V Operation
E) Bar Graph Signal Level Indication

Specifications subject to change without notice.

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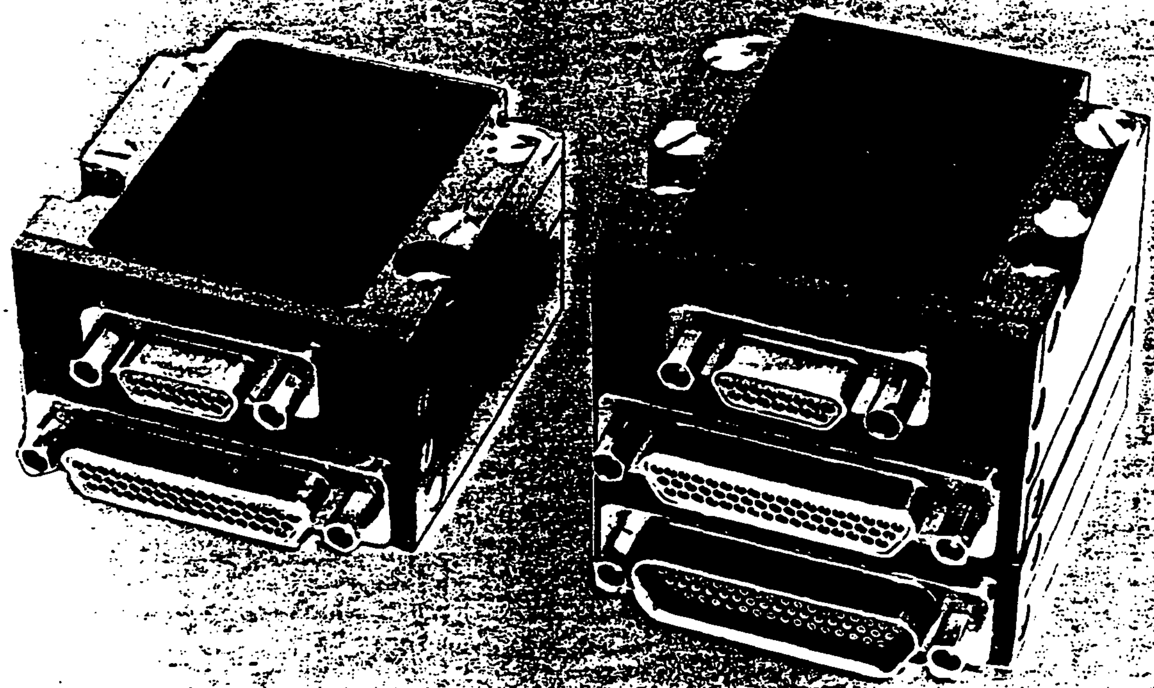
PCM 24A ENCODERS (FIXED FORMAT)



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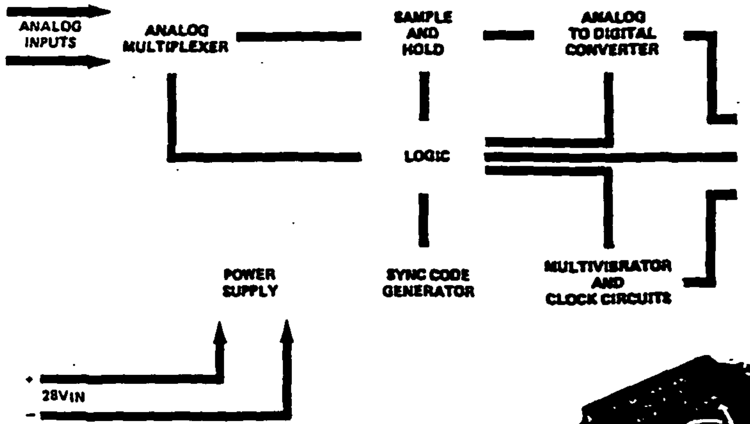
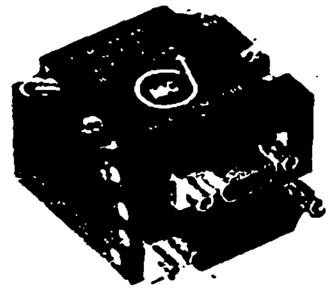
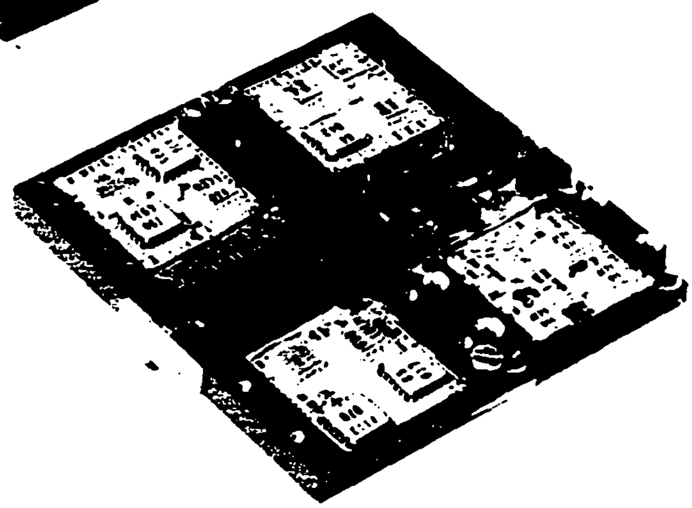






SUBMINIATURE SIZE
FIXED FORMAT
LOW WEIGHT
SELECTABLE BIT RATES
8 OR 10 BIT RESOLUTION
FORBIDDEN CODE CORRECTION
HIGH SHOCK APPLICATIONS – 20,000g
COMPRESSED DATA (Parity Bit Alternative)

The PCM 24A Encoder Series was developed for applications requiring subminiature size, low weight and survivability under high shock conditions. Each Encoder is manufactured in modular form, from housings of high grade aluminum alloy. All electronic circuits are assembled onto ceramic substrates using CLCC and other surface mount devices. These circuits are fixed within each module, then at final assembly and test, the individual modules are hardwired together. This method of electromechanical construction offers extremely rugged, durable and reliable Encoders.

With 48 or 96 Channel (including Sync Words) capability, the PCM 24A is ideally suited for no-nonsense, fixed format encoding. In addition, and by using external connections, the Encoder can be configured for super-commutation and/or external clock input operation.

NOTES:

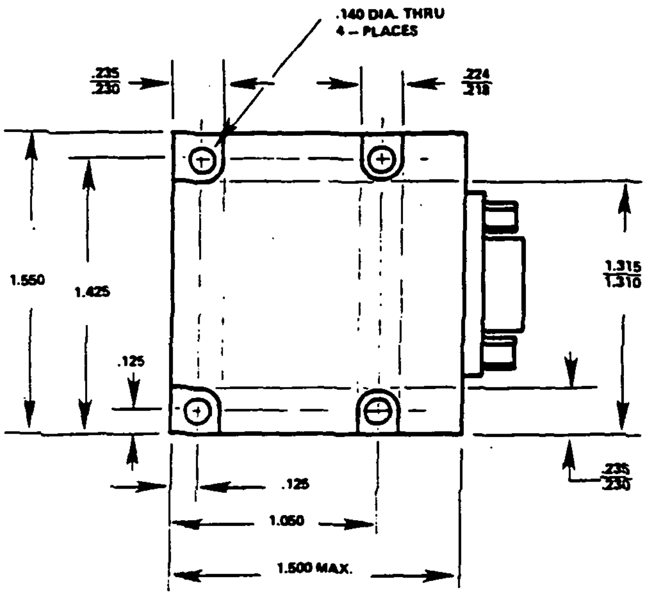
1. Selectable bit rates (divisible by 2 and by 4) – standard on the PCM 24A.
2. With 3 Sync Words (8 Bts/Wd) specified, format will be 24 Bit Barker Code.
   With 3 Sync Words (10 Bts/Wd) specified, format will be 30 Bit Barker Code.
3. Differential inputs/bi-level inputs are not standard on the PCM 24A – consult the factory.
4. Useable data inputs will equate to 48 minus Sync Words or, 96 minus Sync Words.
5. At Bit Rates of 750 KBts/Sec and above, the maximum allowable source impedance will reduce to a maximum of 2 Kohm.
6. Higher environmental capabilities are available – including high shock capability – consult factory.

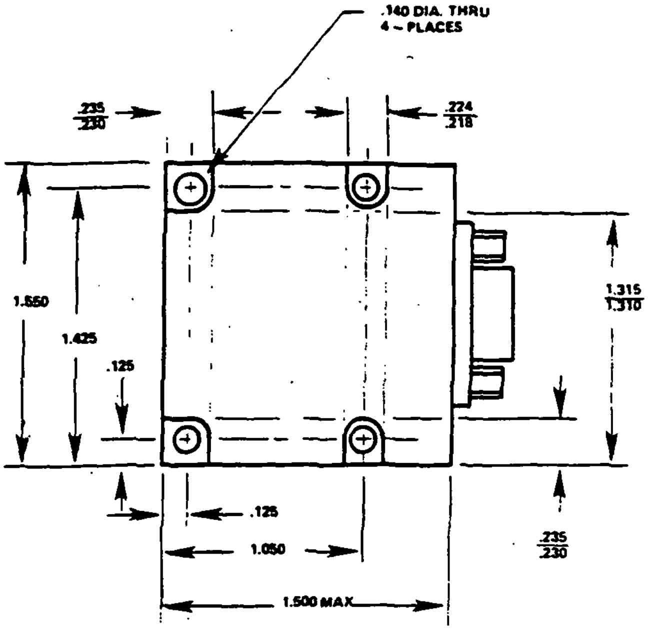
OPTIONS:

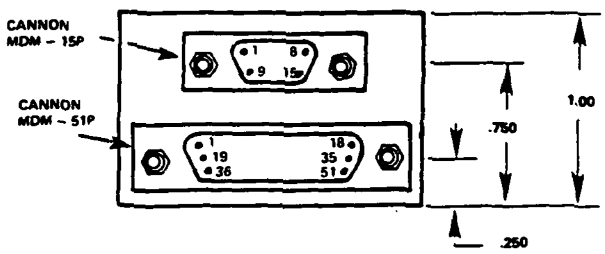
1. Resolution: 10 Bits/Word available – consult factory.
2. Frame Sync: 3 Sync Words available – consult factory.
3. Output Code: Bi-ϕ L output code available – consult factory.
4. Operating Temperature: –40° to 85°C available – consult factory.
5. Forbidden code correction available – consult factory.
6. Compressed data (Parity Bit Alternative) available – consult factory.

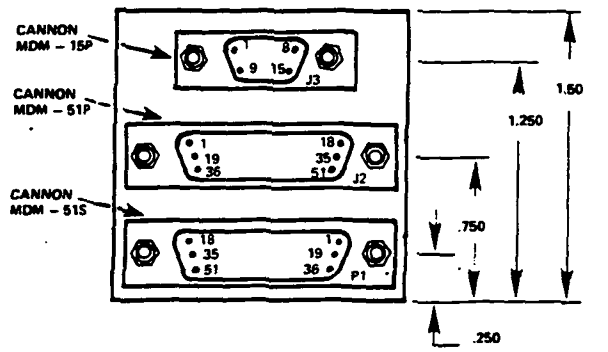
		PCM 24A-48	PCM 24A-96
GENERAL			
Bit Rate	(See Note 1)	1 MBt/Sec. (Max.)	*
Bit Rate Stability		±0.5%	*
Resolution	(See Option 1)	8 Bts/Wd	*
Word Rate		Bit Rate divided by Bits/Word	*
Sample Rate		Word Rate Words/Frame	*
Words/Frame	(Inc. Sync.)	48	96
Frame Sync.	(See Note 2 & Option 2)	2 (16 Bit Barker)	*
Format		Fixed	*
Accuracy	(Overall)	±0.4%, ±½ L.S.B.	*
Output Code	(See Options 3, 5 & 6)	NRZ-L	*
Word Alignment		MSB First	*
Pre-Mod Filter		No	*
Output Amplitude		±2.5V	*
Short Circuit Protection (To Ground)		Yes	
ANALOG MULTIPLEXER (See Notes 3 & 4)			
Single Ended Inputs	(Excl. Sync. Words)	46	94
Input Signal Range	(Specify Choice)	±2.5V or 0-5V	*
Input Impedance		10 Megohm (Max.)	*
Source Impedance	(See Note 5)	10 Kohm (Max.)	*
Crosstalk		±1 L.S.B. (For 35V)	*
Overvoltage		±35V	
POWER SUPPLY			
Input Voltage		28Vdc, ±4Vdc	*
Input Current		100mA (Nom.)	*
Overvoltage Protection		±40Vdc, 1 minute	*
Isolation (Power/Signal Grounds to Chassis)		10 M (Min.)	
DIAGNOSTIC OUTPUTS		Bit Clock, Frame Sync., Frame Sync. divided by 4, NRZ-L	
Output Amplitude		TTL compatible (2 TTL loads)	
ENVIRONMENTAL	**(See Note 6)**		
Temperature	(See Option 4)	Operating: −20°C to 70°C (Baseplate) Non-Operating: −55°C to 100°C	
Vibration		Each Axis: 30g, 20-2000Hz, 0.4" DA (Max.)	
Shock	(See Option 5)	Each Axis: 250g, 11mSec.	
Acceleration		Each Axis: 200g, Linear, 2 Minutes	
Humidity		95% RH, 2 hrs. at 55°C	
Altitude		Unlimited	
MECHANICAL			
Dimensions		See Outline Drawings	
Weight		4 oz. (113 grms) −48	6 oz. (170 grms) −96
Connectors		MDM15, MDM 51	

Specifications are subject to change without notice. Verification can be given upon request.









PIN NO.	FUNCTION
1	INPUT 1
THRU	THRU
43	INPUT 43
44	CHANNELS 12, 24, 36, 48 SYNC.
45	INPUT 44
46	INPUT 45
47	INPUT 46
48	SCOPE SYNC. (FR. SYNC. (0-5V)
49	± 2.5V OUT, NRZ-L
50	+28V
51	+28V RTN. (SIG. GND.)

J2 (MDM 15P)

PIN NO.	FUNCTION
1	BIT RATE OUT (0-5V)
2	NRZ-L OUT (0-5V)
3	CL IN
4	INTERNAL CL OUT
5	INTERNAL ÷ 2 CL OUT
6	INTERNAL ÷ 4 CL OUT
7 THRU 13	NC
14	+28V OUT
15	+28 RTN. (SIG. GND.)

P1 (MDM 51S)

PIN	FUNCTION
1 THRU 48	1 INPUTS THRU 48
49 THRU 51	NC

J2 (MDM 51P)

PIN	FUNCTION
1 THRU 43	49 INPUTS THRU 91
44	CHAN. 24, 48, 72, 96 SYNC.
45	INPUT 92
46	INPUT 93
47	INPUT 94
48	SCOPE SYNC. (FR. SYNC.) (0-5V)
49	+2.5V OUT, NRZ-L
50	+28V
51	+28V RTN. (SIG. GND.)

J3 (MDM 15P)

PIN NO.	FUNCTION
1	BIT RATE OUT (0-5V)
2	NRZ-L OUT (0-5V)
3	CL IN
4	INTERNAL CL OUT
5	INTERNAL ÷ 2 CL OUT
6	INTERNAL ÷ 4 CL OUT
7 THRU 13	NC
14	+28V OUT
15	+28 RTN. (SIG. GND.)

MC²

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